COMMONWEALTH of VIRGINIA

Marine Resources Commission
2600 Washington Avenue
Third Floor
Newport News, Virginia 23607

Douglas W. Domenech
Secretary of Natural Resources

Jack G. Travelstead
Commissioner

December 1, 2013

MEMORANDUM

TO: The Honorable Robert F. McDonnell
Governor of the Commonwealth of Virginia
And,
Members of the Virginia General Assembly

THROUGH: The Honorable Douglas W. Domenech
Secretary of Natural Resources

FROM: Jack G. Travelstead

SUBJECT: Blue Crab Fishery Management Plan

On behalf of the Virginia Marine Resources Commission, I am writing to report on the status and current implementation of the blue crab fisheries management plan, in accordance with the provisions of § 28.2-203.1 of the Code of Virginia.

EXECUTIVE SUMMARY

Results from the 24th Bay-wide Winter Dredge Survey, conducted December 2012 to March 2013 by the Virginia Institute of Marine Science and Maryland Department of Natural Resources, indicate the blue crab stock was not overfished and overfishing did not occur in 2012. The 2012-2013 Winter Dredge Survey estimates of total abundance indicate a 61% decrease in crabs of all sizes compared to the previous year's survey. This total abundance of 300 million crabs was the sixth lowest estimate from this survey that started in the winter of 1989-1990. The abundance of juvenile crabs (both male and female crabs) that measure less than 2.4 inches in carapace width was the second lowest in 24 years, at 111 million crabs. The number of female crabs that could spawn in 2013 was 147 million and ranks seventh highest, for the 24-year Chesapeake Bay-wide survey.

Year-to-year variation in abundance of juvenile blue crabs is expected because of the effects of

An Agency of the Natural Resources Secretariat
www.mrc.virginia.gov
Telephone (757) 247-2200 (757) 247-2292 V/TDD Information and Emergency Hotline 1-800-541-4646 V/TDD

environmental influences on the entrainment of crab larvae from the ocean to the Virginia portion of the Chesapeake Bay. Conservation of female spawning age crabs is the primary management objective to ensuring this juvenile variability does not persist. Since 2008 there has been a continuation, by all Chesapeake Bay jurisdictions, of management measures that conserved the spawning-age female crabs, and the results have been an average of 168 million spawning-age female crabs in the last five years, as compared to the 24-year average of 147 million spawning-age female crabs.

At its October 2013 meeting, the Commission established several management measures pertaining to the winter crab dredge fishery season. For the sixth consecutive season, the winter crab dredge fishery season was closed to allow for continued rebuilding of the spawning stock biomass. The continued closure of the winter dredge fishery season was mainly influenced by the low abundance of juvenile crabs, as juvenile crabs enumerated during the Bay-wide winter dredge survey mature and grow into the fisheries for the next 12 months, and that means a winter dredge fishery would be fishing on a low abundance of primarily female crabs. The Commission was also concerned by the low commercial and recreational harvests throughout the Chesapeake Bay. The Commission did endorse a management framework, for a limited winter crab dredge fishery season, and management triggers to determine when a winter dredge season could open in the future. Those triggers are based on a healthy abundance of juveniles and mature crabs. The Commission also adopted bushel limits for the crab pot fishery, as a management tool, for 2014 and future harvest seasons. However, the Commission determined that bushel limits, alone, might not completely offset a potential loss of spawning potential, from an opening of the winter crab dredge fishery season, at this time.

At its October meeting, the Commission also established several other management measures for the commercial crab pot fishery. The 2013 crab pot season was extended an extra 15 days to December 15, 2013, and license category-specific bushel limits were established to compensate for the projected harvest during both the 2013 season extension and 2014 season. The Commission established the 2014 crab pot and peeler pot commercial harvest seasons for 2014 as March 17 through November 30, for both male and female crabs. This allows for 10 additional days, for the harvest of female crabs, at the end of November.

Virginia crab and oyster industries continue to benefit from disaster relief funds provided in 2009 by the Department of Commerce for the declared Fishery Disaster in the Chesapeake Bay blue crab fisheries. This Disaster Relief Fund has provided various crab industry members (harvesters, buyers, and processors) negatively impacted by poor crab stock conditions during many years through 2007 a source of employment. These funds have provided an opportunity to work in resource or habitat enhancement projects. The total amount of funding from the Disaster Relief Fund was $14,995,000. Of the six project areas detailed in previous reports, the oyster aquaculture project continues in 2013. The oyster aquaculture project has stimulated technical advances in hatchery production which is needed for spat-on-shell operations.

THE 2013 VIRGINIA BLUE CRAB FISHERY MANAGEMENT PLAN

Status of the Blue Crab Stock

The 2011 benchmark stock assessment control rule differs from its interim predecessor in that the reference points are based on the biological status of female crabs, instead of both sexes combined. Biological reference points are the primary outputs of stock assessments, and fishery regulations are implemented to conform to those biological standards. The 2011 blue crab stock assessment provided female-only reference points for both the abundance of female crabs at least 2.4 inches in carapace width and the annual removal rate that is based on the percentage of female crabs of all sizes that are harvested in a year.

The abundance and exploitation rate targets and thresholds (biological limits) currently used to monitor the health of the blue crab stock in the Chesapeake Bay are provided in Table 1 below.

Table 1. Abundance and exploitation rate targets and thresholds for the Chesapeake Bay blue crab stock.

2011 Stock Assessment – Biological Reference Points		
Abundance	Overfished	70 million age 1+ female crabs
	Target	215 million age 1+ female crabs
Exploitation Rate	Overfishing	34% of all female crabs
	Target	25.5% of all female crabs

The abundance estimate from the 2012-2013 Bay-wide Winter Dredge Study of female spawning-age crabs (age 1+) was 147 million crabs, representing a 55% increase from the 2011-2012 Winter Dredge Survey results. Spawning age crabs are crabs (at least 2.4 inches in carapace width) sampled by the survey, and these crabs will spawn either in late May or during the July-August peak spawning period. While this estimate is below the target of 215 million spawning-age female crabs, it is above the overfished threshold of 70 million crabs, indicating the stock is not overfished. The most recent (2012) female-crab exploitation rate estimate was 10%, which is well below the target exploitation rate of 25.5% removal of female crabs on an annual basis, from fisheries, alone. This estimate is below the overfishing threshold of 34%, and overfishing is not occurring on this stock. For five consecutive years the target removal rate has been near or less than the target.

The total abundance of 300 million crabs was the fifth lowest estimate in the 24 year time series of the Winter Dredge Survey. The decline in total abundance from the highest estimate in 2012 may be a result of the 2012 juvenile crabs not recruiting into the fishery because of low survival. Anecdotal comments from harvesters indicated this lack of recruitment may be a result of predation, and there have been suggestions from the scientific community that cannibalism increases when juvenile abundance increases. Predators, such as juvenile red drum (puppy drum) were in higher abundance in the Virginia portion of the Chesapeake Bay in 2012, but it is inconclusive to say that puppy drum distributions were higher throughout the entire bay region. Environmental factors could have also influenced the survival of the 2012 juvenile crabs. Dr. Thomas Miller, Director of the Chesapeake Biological Laboratory in Maryland, suggested that a long, cool spring in 2012 could have slowed the growth cycle of juvenile blue crabs, making them more susceptible to predation for an extended period of time. The low abundance of submerged aquatic vegetation (SAV; underwater sea grasses) may have also influenced blue crab survival.

In the 2013 Chesapeake Bay Blue Crab Advisory Report, the Chesapeake Bay Stock Assessment Committee (CBSAC) recognized these issues as a critical data and analysis need. The CBSAC has identified a list of fishery dependent and independent data needs that would provide better information on blue crab abundance and survival, such as in 2012, for management measures, to include:

- Improving estimates on overwintering mortality;
- Increasing access to summer survey data for analysis;
- Analysis of environmental and ecological variables that affect survival and recruitment;
- Adding a shallow water survey to sample juvenile blue crabs; and
- Analyzing the magnitude of other sources of incidental mortality (e.g. sponge crab discards, unreported losses after harvest from the peeler crab fishery, and disease).

Table 2 below provides a 24 year summary of the results from the Chesapeake Bay-wide Winter Dredge Survey conducted by the Virginia Institute of Marine Science (VIMS) and the Maryland Department of Natural Resources (MDDNR). The abundance of recruits (termed age-0 crabs) and the spawning-age crabs (termed age-1+) are differentiated according to size, with 2.4 inches in carapace width as the separator between the two size classes. Any abundance estimate represents the number of crabs that will be available to the Chesapeake Bay fisheries following the end (March) of the seasonal (December-March) Bay-wide Winter Dredge Survey (Figure 1).

Table 2. Bay-Wide Winter Dredge Survey results (1990 through 2013). All surveys begin in December and ended in March of the next year.

Survey Year (Year Survey Ended)	Total Number of Crabs in Millions (All Ages)	Number of (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
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	By 2014	By 2014

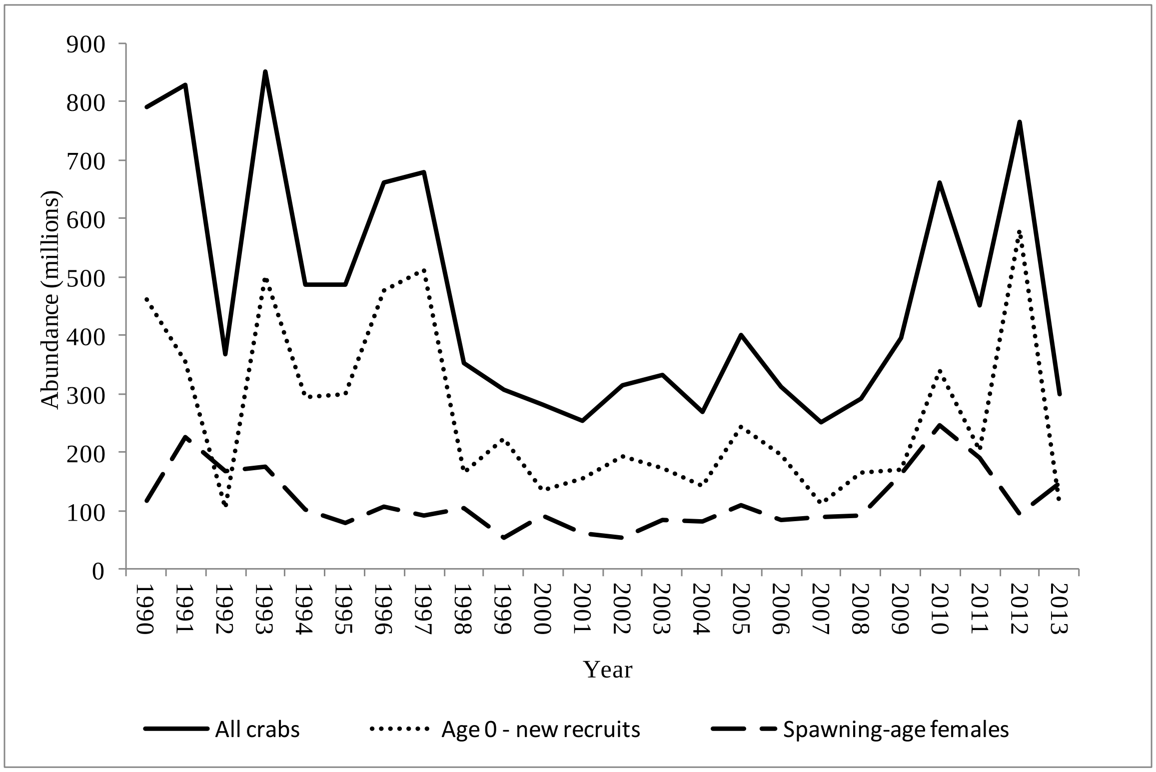


Figure 1. Abundance estimates (number of crabs in millions) for the 24 year Bay-wide Winter Dredge Survey for total crab abundance (male and female), juvenile (recruits) crab abundance, and spawning-age (age-1+) female crab abundance, 1990 through 2013.

Harvest and Effort Statistics

In May 2013, the CBSAC reported (Attachment I) the 2012 Bay-wide crab commercial harvest was 56 million pounds, 17% lower than the 2012 Bay-wide crab harvest of 67 million pounds. The Bay-wide recreational harvest was estimated as 3.9 million pounds. Of the Bay-wide commercial harvest, Maryland harvested 31 million pounds, Virginia harvested 21 million pounds, and 3.5 million pounds was harvested in the jurisdiction of the Potomac River Fisheries Commission. The total 2012 reported commercial harvest for all Virginia tidal waters, including the bays and tributaries seaside of the Eastern Shore and Virginia Beach, was 24.8 million pounds.

Figure 2 below displays the time series of Virginia commercial crab harvest for all Virginia waters in pounds and estimated dockside value (first sale from harvester). The dockside value has been adjusted to account for inflation using the Consumer Price Index. Harvest statistics have been collected from Virginia fisheries since the last 1920s; however, 1994 is the first representative year of the mandatory commercial harvest reporting system. Both harvest and value are following the same downward trend, from 2009-20111, for 2012.

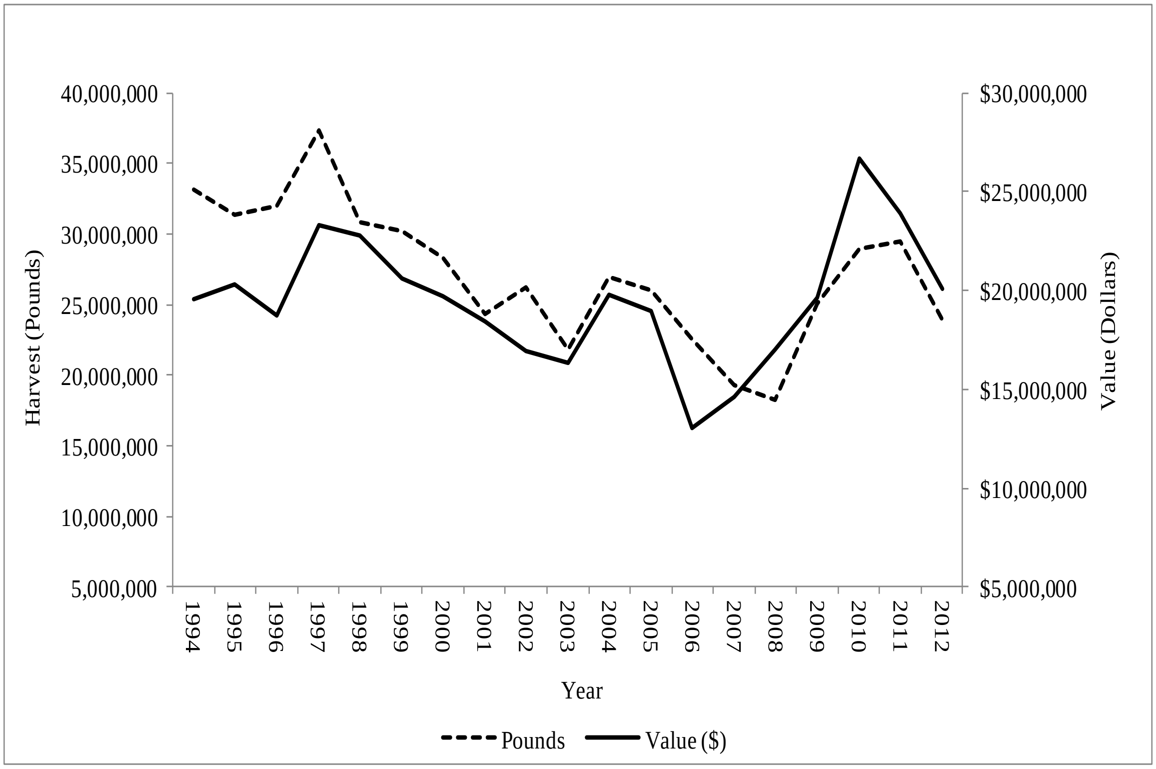


Figure 2. Virginia commercial harvest (state waters, in pounds) of blue crab and estimated dockside value (US dollars adjusted for inflation, first sale from harvester) for 1994 through 2012.

Table 3 below contains Virginia harvest data by market category (hard crabs and peeler and soft crabs), in pounds, for the last five years of complete data by month (2008 through 2012). The hard crab pot fishery has accounted for approximately 96% of the total crab harvest from Virginia tidal waters in recent years. The hard crab pot harvest is dominated by female blue crabs. In 2012 the sex composition was 68% female, compared to 66% female in 2011, 60% female in 2010, 66% female in 2009, and 61% in 2008.

Table 3. Virginia harvest data (state waters only, in pounds) by market category (hard crabs and peeler and soft crabs) for 2008 through 2012 by month. CD indicates confidential data.

Year	March	April	May	June	July	August	September	October	November	December	Total
	Hard Crab Market Category										
2008	528,433	2,007,638	1,515,282	2,427,219	3,154,805	2,936,971	2,493,629	2,253,737	194,363	0	17,512,077
2009	332,795	4,076,678	3,159,973	3,390,142	3,288,526	3,522,741	3,069,006	3,020,995	1,053,336	0	24,914,191
2010	394,013	4,857,355	3,094,440	3,947,409	4,166,862	4,129,891	3,392,980	3,350,045	1,404,170	0	28,737,165
2011	1,207,562	5,095,184	3,676,185	3,849,809	3,893,481	3,742,746	3,465,122	2,964,902	1,358,723	0	29,253,712
2012	2,590,763	2,638,424	3,490,971	3,639,743	3,242,320	2,967,967	1,953,971	2,186,948	901,192	124,052	23,736,350
	Peeler and Soft Crab Market Category										
2008	0	31,745	441,368	140,844	146,504	108,830	82,489	11,545	0	0	963,324
2009	0	13,621	404,733	154,650	164,728	138,390	85,534	19,662	0	0	981,319
2010	0	59,186	409,174	155,276	186,811	141,948	89,111	15,733	0	0	1,057,239
2011	0	26,976	355,754	137,249	163,484	122,531	90,881	3,547	0	0	900,422
2012	2,327	138,390	228,083	156,621	172,017	128,400	77,760	14,262	CD	0	917,861

Table 4. Number of harvesters by month for 2009 through 2012 active in the crab pot fishery.

Year	March	April	May	June	July	August	September	October	November	December
2008	231	429	513	583	593	571	530	461	131	0
2009	199	463	600	683	708	719	619	509	263	0
2010	171	491	636	670	668	630	557	433	231	0
2011	298	497	607	646	632	593	504	401	253	0
2012	384	493	600	637	609	570	500	392	213	43

Table 5. Number of harvesters by month for 2009 through 2012 active in the peeler pot fishery. CD indicates confidential data.

Year	March	April	May	June	July	August	September	October	November	December
2008	0	59	289	145	140	122	87	37	0	0
2009	0	48	354	214	193	186	114	47	0	0
2010	0	88	302	172	150	136	98	38	0	0
2011	0	61	273	154	139	120	80	26	0	0
2012	8	171	233	156	136	137	94	33	CD	0

Tables 4 and 5 above depict effort (the number of active crab harvesters) in the crab pot and peeler pot fisheries for the last four years of complete data, by month (2009 through 2012). June through August is the peak time period for active harvesters in the crab pot fishery. Harvester activity in the peeler pot fishery peaks in May and gradually declines from June through November.

Tables 6 and 7 below depict Virginia trip data for the last four years of complete data. The number of trips with reported crab harvest from crab pot gear totaled 52,989 in 2012 (compared to 55,324 crab pot harvest trips in 2011). The number of peeler pot trips in 2012 totaled 12,451 (an increase from 11,027 trips in 2011). Harvesters are most active from May through September in the crab pot fishery, while peeler pot trips peak in May, with a gradual decline from June through October.

Table 6. Number of commercial trips by month for 2009 through 2012 taken in the crab pot fishery.

Year	March	April	May	June	July	August	September	October	November	December
2008	1,390	5,082	5,267	7,418	8,242	7,497	6,041	4,852	818	0
2009	938	5,911	6,951	9,149	10,103	9,661	7,486	5,796	2,096	0
2010	1,064	6,749	7,663	9,187	9,490	8,415	6,688	4,850	1,897	0
2011	1,985	6,675	7,475	8,972	8,813	7,976	6,392	4,635	2,212	0
2012	2,996	5,478	8,116	8,456	8,370	7,770	5,514	4,328	1,705	256

Table 7. Number of commercial trips by month for 2009 through 2012 taken in the peeler pot fishery. CD indicates confidential data.

Year	March	April	May	June	July	August	September	October	November	December
2008	0	330	3,796	2,112	2,237	1,860	1,122	218	0	0
2009	0	236	4,340	2,838	2,981	2,616	1,510	294	0	0
2010	0	637	4,075	2,361	2,546	1,908	1,196	209	0	0
2011	0	329	3,605	2,134	2,282	1,714	1,155	118	0	0
2012	29	1,735	3,048	2,195	2,178	2,003	1,053	207	CD	0

Blue Crab Conservation Actions in 2013

Since 1994, Commission actions that have attempted to promote sustainability of the blue crab stock and fishery through conservation measures are included in Attachment II. These measures have helped in rebuilding the crab stock and improving our fishery harvests. In 2013, the Commission held a public hearing on October 22 to review blue crab conservation issues, and hear comments from the public and industry. The decline in juvenile crab abundance, as well as the low total abundance of crabs in the 2012-2013 Winter Dredge Survey warranted caution in the relaxation of conservation measures, many of which have been in place since 2008. The three Chesapeake Bay jurisdictions have agreed that any increase in harvest expected from a new management measure will be compensated for by another conservation measure. After a presentation by the VMRC staff on several proposed management measures and hearing public comments, the Commission approved the following management measures at its October 2013 meeting:

- Winter crab dredge fishery season

The Commission closed the winter crab dredge fishery season for the sixth consecutive season after reviewing the possibility for a limited, controlled opening of the 2013-2014 winter crab dredge fishery season. Public opinion remains in opposition to this fishery, and other sectors of the commercial crab industry also expressed opposition to the 2013-2014 opening. The Commission chose to minimize risk to the blue crab stock.

While the Commission determined the winter crab dredge fishery season should remain closed for the 2013-2014 season, the Commission endorsed a management framework for a future limited and tightly controlled winter crab dredge fishery season. This management framework would be used to regulate the limited winter crab dredge fishery season when abundance of all sizes of blue crab are sufficient to allow the Commission to consider an opening of this fishery. These management triggers that would promote a possible opening of the crab dredge fishery are illustrated by an example in Table 8. This is one example, and the CBSAC will help to determine the final set of abundance triggers. These triggers can only be considered by the Commission when the previous exploitation or removal rate is at or near the target.

The management framework was developed with input from industry members at a Winter Crab Dredge Working Group meeting in September 2013, as well as the Crab Management Advisory Committee (CMAC) at its' October 2013 meeting. The management framework establishes provisions for a limited winter crab dredge fishery season including limited entry, harvest limitations, establishment of a limited crab dredge harvest area, bycatch prohibitions, licensees requirements, gear limitations, and establishment of a fishery season as well as vessel and gear requirements.

Table 8. Management trigger framework developed by staff based on years with a female exploitation rate less than 34%. The mean and the mean plus or minus one standard error of the mean for total crab abundance, juvenile crab abundance, and spawning-age female crab abundance are used to select management actions.

- Extension of fall 2013 crab pot season to December 15, and establishment of the 2014 crab pot season with bushel limits, as a conservation equivalency measure

	Total Number of Crabs in Millions (All Ages and Both	Number of Juvenile Crabs in Millions (both sexes)	Number of spawning age Female crabs in Millions	Management Action
Mean + One S.E.*	536	293	128	Liberalize crab management when all three indices are above mean plus one standard error
Mean*	494	264	118	No recommended crab management changes if between upper and lower boundaries of the mean
Mean - One S.E.*	453	234	107	Crab management reductions if all three indices are below the mean minus one standard error
* Based on years with a female exploitation fraction less than 34% (years are highlighted in table)				

The Commission extended the 2013 and 2014 crab pot seasons for male and female blue crabs. The 2013 crab pot season was extended to December 15, 2013, representing an additional 15 days of harvest for male crabs and an additional 25 days of harvest for female crabs. The 2014 crab pot season was extended to November 30, 2014 for both male and female crabs (representing an additional 10 days of harvest for female crabs). The Commission also established crab pot license-specific bushel limits for the 2013 extension (December 1 through 15, 2013) and the 2014 season (March 17 through November 30, 2014) to compensate for the projected potential additional exploitation of the female crab component of the stock. This means that an expected fall 2013 increase in crab harvest will be compensated for with the bushel limits established at the October meeting. This conservation equivalency is based on compensating for lost spawning potential (females crabs) in 2013. Originally, the 2013 female crab pot season would have ended on November 20, 2013, and the male crab pot season would have ended on November 30, 2013. Table 9 below gives the bushel limits by crab pot license category

Table 9. Crab pot gear license category-specific bushel limits for the 2013 crab pot season extension (December 1 through December 15, 2013) and the 2014 crab pot season (March 17 through November 30, 2014).

- Establishment of the 2014 Crab Agent Requirements

License Category	Bushel Limt
Crab Pot 85 or Less	16
Crab Pot 127 or Less	21
Crab Pot 170 or Less	27
Crab Pot 255 or Less	43
Crab Pot 425 or Less	55

The Commission established a declaration date for agent use requirements in the crab pot fishery for the 2014 season. The declaration date will require crab licensees with approved agents in 2012, and who have complied with all reporting requirements, to submit a 2014 crab agent registration application to the Commission by March 1, 2014 to be eligible for one of the 153 agent slots. If the number of applications by eligible licensees as of March 1, 2014, is less than the approved 153 agent slots, then any application for a crab agent will be considered, on a first-come, first-serve basis, until the 153 agent slots are filled.

Winter Blue Crab Dredge Mortality Project

The Commission funded a Winter Crab Dredge Study in 2012. The study, designed by scientists at VIMS, with input from VMRC staff, and industry representatives, estimated non-harvest (or discard) mortality caused by crab dredge gear. The study report is included in Attachment III. Prior to this study, discard mortality estimates were outdated. Results indicated a higher discard mortality of blue crabs when fishing occurred on sandy (hard) substrate compared to mud (soft) substrate. Discard mortality was lower when crab dredge gear was not equipped with divers in either substrate. Divers are weights that can be mounted onto a dredge, and have been used to increase the stability of the gear as well as increase gear efficiency. The results from this study aided the Commission's decision on the 2013-2014 winter crab dredge fishery season, as well as in developing the management framework for a limited winter crab dredge fishery season. Results from the study were used in developing the limited crab dredge harvest area, bycatch prohibitions, and gear restrictions. Additionally, the CBSAC has recommended that the Bay jurisdictions seek incidental mortality estimations for all major crab gears. These estimates have been labeled as a critical data need by the CBSAC. Expenditures for this project were $98,000, and were paid for by the Marine Fishing Improvement Fund.

Ecosystem Constraints on the Blue Crab Resource

§ 28.2.203.1 of the Code of Virginia provides that the blue crab fishery management plan shall be designed to reverse any fishing practices, environmental stressors, and habitat deterioration negatively impacting the short and long term viability and sustainability of the crab stock in Virginia waters. In recent years, the Commission has adopted effective conservation measures to reverse fishing practices that have negatively impacted the stock. The Commission relies on the efforts of its sister agencies to promote and sponsor improvements in the Chesapeake Bay's water quality in order to meet the requirements of §28.2.203.1 of the Code of Virginia dealing with environmental stress and habitat deterioration.

The Commission participated in a Harmful Algal Bloom (HAB) Task Force meeting to provide updated information on the 2012 HAB season. The HAB Task Force is planning to meet in either late 2013 or early 2014 to review the 2013 season and emerging species of concern. The 2013 season has been a relatively slow season for *Microcystis spp.* blooms. An emerging species of concern, *Alexandrium monilatum*, will be discussed, although the impact on blue crab meat safety or health is unknown at this time because no scientific studies have been conducted. The relevance of algal blooms to blue crab relates to the negative impact of blooms on oxygen content in the water. Hypoxic and even anoxic conditions can be associated with algal blooms, and blue crab can be displaced or experience mortality events under very low oxygen conditions.

The Commission and the industry recognize that improvements in blue crab habitat and water quality could increase the probability for improved recruitment to the stock and fisheries; however, many water quality and habitat impacts on this stock are not fully quantified or understood. The relationship between blue crabs and other components of the ecosystem is being explored by Chesapeake Bay scientists. Many natural and man-induced impediments continue to challenge the stability of the blue crab stock, including hypoxia (low oxygen levels in the water), shoreline development, and pollution. The issue of climate change will continue to be important as well, as crab behavior is linked to water temperature.

Water quality in the Chesapeake Bay is improving due to the ongoing efforts of the Commonwealth and the signatories of the Chesapeake Bay Agreement. Additional work is being implemented to meet pollution reduction goals in the Chesapeake Bay. Each of the jurisdictions has developed a Watershed Implementation Plan to guide restoration plans through 2025. The federal government developed Executive Order 13508, which guides the federal agencies plan to meet pollution reduction goals and establishes the Federal Leadership Committee that will publish an annual Chesapeake Bay Action Plan. The fiscal year 2013 Action Plan was published by the Federal Government in November 2012.

The reduction in SAV beds has also likely impacted the blue crab stock, especially juvenile crabs that use SAV beds as protection from predators. Seagrass beds provide nursery habitat for newly settled, young juvenile, and mating blue crabs. Since 2001, the Commission has approved a set-aside area for SAV restoration in South Bay. In 2006, this area was expanded to total 727.85 acres of protected area. The South Bay set-aside area has developed into one of the largest eelgrass beds in the lower Delmarva Peninsula and is now self sustaining. In 2011, the Commission voted to protect this set-aside area for an indefinite amount of time. Dredging is also prohibited in the protected area.

The importance of eelgrass habitat functions in Chesapeake Bay was first demonstrated by the VIMS in a 1961 report to the National Science Foundation. Eelgrass is the dominant SAV in Virginia waters. Subsequent studies by VIMS have led to a greater understanding of SAV Bay-wide distribution, abundance, and health. The VIMS established the first broad-scale aerial monitoring of SAV in 1974, and expanded the survey in 1978 to cover all of Virginia's tidal waters. The VIMS maintains a research and monitoring program that has significantly expanded our understanding of SAV, its role in the greater Bay ecosystem, and its linkages with the health of the blue crab stock. Ongoing SAV research and monitoring programs include:

- Annual Bay wide aerial survey
- Eelgrass restoration in Virginia's seaside bays
- The use of restored eelgrass beds by estuarine fauna
- Targeted monitoring and study of key SAV locations in Virginia waters for effects from global warming and climate change
- Assessment and monitoring of the effects of certain fishing techniques on eelgrass beds
- Water quality assessments for evaluation of water quality standards attainment (SAV distribution is a criterion for water clarity)
- The role of abiotic factors influencing the flowering of eelgrass
- The roles of dispersal and seed predation in determining eelgrass population dynamics
- The influence of climate change factors on the use of eelgrass and widge on grass beds
- Habitat suitability of exotic algae versus native seagrass as an alternative nursery habitat for juvenile blue crabs
- The distribution of overwintering age-0 blue crabs in shallow water habitats
- The functional relationships between seagrass characteristics and juvenile blue crabs under high recruitment

As is evident from some of the VIMS monitoring and research, there is great concern in the scientific community regarding the fate of SAV in Chesapeake Bay, and the effect that losses will likely have on blue crabs and other Bay fauna. The survival of most species of SAV is viewed as highly problematic as sea levels rise and water temperature continues to increase. The VIMS studies have shown that there is a strong affect of high summertime water temperatures on the seagrass declines observed in Virginia waters in recent years (Moore and Jarvis 2008; Moore et al. 2012), and that short term periods of high temperatures can cause large die-offs. This is due, in large part, to the high temperature intolerance of eelgrass. Eelgrass is near its southern limits along the Atlantic coast in Virginia, so high summertime water temperatures can be especially harmful to eelgrass beds. Unusually high temperatures during periods in the summer of 2005 and 2010 resulted in severe diebacks in eelgrass beds. After each of these diebacks, some recovery was observed over the next few years; however, VIMS research (Jarvis and Moore 2010) has shown that since eelgrass seeds in the sediment are only viable for a year or less, consecutive years of diebacks would be especially deleterious. If water temperatures continue to increase due to a changing climate, losses of eelgrass beds in Virginia may accelerate. The VIMS research has demonstrated that increased water clarity can help eelgrass beds persist under higher temperatures. Therefore, VIMS is working with Virginia regulatory agencies, MDDNR, and the Environmental Protection Agency to assess the current water clarity goals for the Chesapeake Bay to determine if changes are appropriate and needed. Storms can also be stressful to SAV beds through direct physical disruption or by greatly increasing sediment and nutrient inputs into the Bay and its tributaries. Excess sediments and nutrients can promote increased turbidity, compounding the effects of high temperatures (Moore et al. 2013). Results of VIMS' studies indicate that Virginia's SAV beds do relatively well in withstanding the direct physical disruption by storms.

Should regional climate change significantly affect SAV distribution and abundance in the Chesapeake Bay, VIMS scientists have found that the coastal bays on the seaside of Eastern Shore may ultimately be a prime refuge location for SAV due to the proximity of these beds to the cooler waters of the adjacent Atlantic Ocean (Orth et al. 2010, Moore et al. 2012). The SAV restoration efforts have been highly successful within the Eastern Shore's coastal bays, and there is much promise of continued growth through natural processes and additional restoration (Orth et al. 2010).

The VIMS annual Bay-wide aerial survey serves as a significant indicator of Bay health, and as a tool for determining compliance with Virginia water quality standards. Virginia tidal waters are home to 12 species of SAV, but it is eelgrass (*Zostera marina*) and widgeongrass (*Ruppia maritima*) that have the most overlap with the distribution of juvenile blue crabs in the Chesapeake Bay. Since the historically low abundances of 1984, SAV restoration has varied between tidal waters with different salinities. Seagrass beds have continually increased in lower salinity tidal waters; increased initially in areas of medium-salinity followed by irregular annual abundance levels; and also increased initially in the high-salinity region followed by a general decline in abundance (Orth et al. 2010). These general trends remain accurate for the years since this study. Due to the complexity of the estuarine environment, it is difficult to accurately determine a primary factor behind SAV declines, especially in individual beds, but Orth et al. (2010) found strong negative correlations between SAV abundance and nitrogen levels. This provides strong evidence that water quality is a primary causative element in SAV distribution and decline. It is understood through numerous published studies that most estuarine fauna, including juvenile blue crabs, generally experience higher growth and survival rates in vegetated versus unvegetated shallow water habitats. A recent VIMS study (Ralph et al. 2013), has shown that juvenile blue crabs prefer denser SAV beds over thinner beds, which further demonstrates the positive influence that the quality of seagrass beds have on blue crab population dynamics. The VIMS also has demonstrated a high value to juvenile blue crabs for unvegetated areas both adjacent to salt marshes in upriver areas of Bay tributaries and areas that contain an abundance of food such as clams and polychaetes (marine worms); and within areas of abundant macroalgae where native SAV nursery habitat has experienced reductions in aerial coverage (Seitz et al. 2003, Seitz et al. 2005, Johnston and Lipcius 2010, Seitz et al. 2011).

Although crustacean pathogens have not yet resulted in large scale impacts to blue crab stock or the fisheries in Chesapeake Bay as they have in several other crab fisheries (Shields 2012), they are present in Virginia tidal waters. The presence and occurrence of these crustacean pathogens has been a long-time research focus of VIMS. The genus *Hematodium* is a parasitic dinoflagellate that is found primarily in the higher salinity waters of the Bay adjacent to the seaside of Eastern Shore. *Hematodium* levels peak in late autumn and their numbers rapidly decline with the onset of cooler winter temperatures (Messick and Shields 2000). Epidemiological risk appears to be highest during molting in juvenile blue crabs, which generally overlaps with the peak autumnal levels of the pathogen. Mortality levels of 87% have been observed in laboratory experiments (Shields and Squyars 2000). The VIMS scientists recently discovered and described the complete life cycle of one species of *Hematodium* for the first time (Li et al. 2011), which will lead to a greater understanding of the risk of mortality and the environmental and biological factors that may influence the effects of this genus of pathogen.

Blue Crab Disaster Relief Funding Updates

In 2008 Virginia was awarded $14,995,000 in disaster relief funds, by the National Marine Fisheries Service (NMFS), after the declaration of a blue crab fishery disaster. The Commission implemented a set of six projects (Items I through VI, below), beginning in December 2008 with the Derelict Crab Pot and Marine Debris Removal Project. The remaining five projects were initiated in 2009, and one has continued in 2013.

I. Derelict Blue Crab Pot and Marine Debris Removal Project

Discarded debris such as tires, gill nets, appliances, and crab pots can be found throughout the tidal waters of Virginia. Derelict crab pots may remain in the environment for years continuing to capture and kill fish, shellfish, birds and marine mammals, including endangered or threatened species. It is estimated that around 20% of crab pots deployed are lost each season, and each functional lost crab pot can continue to capture about a bushel of market-sized crabs per season. There is an environmental benefit in removing marine debris from Virginia's waters, if the removal can be accomplished safely and without damaging the marine habitat and ecosystem. This project includes work specifically aimed at removing marine debris from Virginia's tidal waters with the assistance of watermen. This program recovered over 32,000 crab pots over the four winters from 2008-2012.

II. Cull Ring and Terrapin Excluder Device Project

The goals of this study were to employ Virginia's watermen (1) to investigate the effects of different crab pot cull-ring sizes on blue crab catch, biomass, and survival, and (2) to determine the effects of bycatch reduction devices (BRDs) in crab pots on blue crab catch, finfish bycatch, and diamondback terrapin bycatch. The BRDs were found to exclude all but the smallest terrapins without affecting the catch of crabs (Rook et al. 2010). These pots have been accepted for use in the recreational crab fishery.

III. Supplemental Funding for the Fishery Resource Grant Program

Restoration activities for the blue crab population in the Chesapeake Bay have included several new restrictions on the harvest by Virginia. These new regulations affect the livelihoods of Virginia harvesters targeting blue crabs. In order to supplement the income of these harvesters to maintain their financial stability in response to the 2008 blue crab harvest restrictions, the state proposed to support harvesters by training them in oyster aquaculture. Funding was used to employ one fulltime advisory service person to assist the blue crab harvesters in their new venture into oyster aquaculture. Two methods of oyster aquaculture were implemented, cultch less and remotes setting. Three full years of aquaculture training were supported with additional educational effort in shellfish handling, storage, and transportation. Surveys of participants indicate a strong willingness to continue to develop their shellfish aquaculture enterprises.

IV. Oyster Aquaculture

In 2010, the Commission's Conservation and Replenishment Department began training crab industry participants in modern techniques for growing oysters on private grounds. These techniques are easily adaptable to boats and equipment available to crab harvesters, and should provide alternative sources of income for the harvesters active in the blue crab fishery. More than 130 watermen were trained in cage aquaculture in 2010 and 2011; and all individuals have harvested their first crop of oysters. Many individuals have purchased additional oyster seed and equipment to continue growing oysters after the completion of their training projects. More than 90 other blue crab industry participants were trained in spat-on shell oyster production in 2010 through 2012, and have also begun harvesting their oysters. With the spat-on-shell method, oyster larvae are set on shells in large tanks to produce oyster seed that is very similar to wild oyster seed. More oysters are produced by growing them loose on the bottom in this technique, with less labor. The oysters produced in this manner are primarily used for the shucking industry. In all of the training projects, selectively bred, disease tolerant, triploid (reproductively sterile) oysters are being grown. These oysters are highly marketable because of superior meat quality year round. Blue crab industry participants were again trained in 2013 in oyster aquaculture. More than 20 individuals participated in the spat-on-shell program in 2013. In total, 23,715 bushels of shells were set with .78 billion eyed larvae produced by Virginia hatcheries. These shells were deployed with 160 million small oysters on private oyster beds throughout Virginia's Chesapeake Bay and tributaries. This year was the most productive for this project to date. The growth of private oyster hatcheries in Virginia has been hastened by these projects over the past three years, which has given needed stability to this new industry. Harvests of oysters from private oyster ground have increased significantly over the past three years due partly to the success of this project.

V. Crab Pot and Peeler Pot License Buy Out Program

The Crab License Buy-Back Program was initiated and completed in 2009, in order to reduce the overcapacity in the crab pot and peeler pot fisheries. In total, 75,441 crab pots or peeler pots and 359 crab licenses were purchased and removed from future fisheries. Overcapacity remains an issue in the crab fisheries.

VI. Update of the blue crab stock assessment

In 2013, the CBSAC Report was completed (Attachment I). Findings of the stock assessment were endorsed by the Chesapeake Bay Program Sustainable Fisheries Goal Implementation Team's executive committee. The executive committee is represented by the Marine Resources Commission, the Maryland Department of Natural Resources, the Potomac River Fisheries Commission, the National Oceanic and Atmospheric Administration's Chesapeake Bay Office, Maryland Sea Grant, the Atlantic States Marine Fisheries Commission, and the District of Columbia's Division of Fish and Wildlife.

Managers and scientists expect the annual estimates of abundance and exploitation rate to vary. However, if at any time the Bay-wide Winter Dredge Survey results indicate the abundance of female spawning-age crabs has fallen below the overfished level of 70 million, then management measures would be implemented to protect the blue crab stock.

References

Jarvis, J.C., and K.A. Moore. 2010. The role of seedlings and seed bank viability in the recovery of Chesapeake Bay, USA, *Zostera marina* populations following a large-scale decline. Hydrobiologia 649: 55-68.

Johnston, C.A., and R.N. Lipcius. 2012. Exotic macroalga *Gracilaria vermiculophylla* provides superior nursery habitat for native blue crab in Chesapeake Bay. Marine Ecology Progress Series467: 137-146.

Li, C., T.L. Miller, H.J. Small, and J.D. Shields. 2011. In vitro culture and developmental cycle of the parasitic dinoflagellate *Hematodinium* sp. from the blue crab *Callinectes sapidus*. Parasitology 138: 1924-1934.

Moore, K.A., and J.C. Jarvis. 2008. Environmental factors affecting recent summertime eelgrass diebacks in the lower Chesapeake Bay: implications for long-term persistence. Journal of Coastal Research 55: 135-147.

Moore, K.A, E.C. Shields, D.B. Parrish, and R.J. Orth. 2012. Eelgrass survival in two contrasting systems: role of turbidity and summer water temperatures. Marine Ecology Progress Series 448: 247-258.

Orth, R.J., M.R. Williams, S.R. Marion, D.J. Wilcox, T.J.B. Carruthers, K.A. Moore, W. M. Kemp, W.C. Dennison, N. Rybicki, P. Bergstrom, and R.A. Batiuk. 2010. Long-term trends in submersed aquatic vegetation (SAV) in Chesapeake Bay, USA, related to water quality. Estuaries and Coasts 33: 1144-1163.

Ralph, G.M., R.D. Seitz, R.J. Orth, K.E. Knick, and R.N. Lipcius. 2013. Broad-scale association between seagrass cover and juvenile blue crab density in Chesapeake Bay. Marine Ecology Progress Series 488: 51-63.

Seitz, R.D., R.N. Lipcius, W.T. Stockhausen, and M.M. Montane. 2001. Efficacy of blue crab spawning sanctuaries in Chesapeake Bay. Spacial Processes and Management of Marine Populations, Alaska Sea Grant College Program. 607-626.

Seitz, R.D., R.N. Lipcius, W.T. Stockhausen, K.A. Delano, M.S. Seebo, and P.D. Gerdes. 2003. Potential bottom-up control of blue crab distribution at various spatial scales. Bulletin of Marine Science 72(2): 471-490.

Seitz, R.D., R.N. Lipcius, and M.S. Seebo. 2005. Food availability and growth of the blue crab in seagrass and unvegetated nurseries of Chesapeake Bay. Journal of Experimental Marine Biology and Ecology 319: 57-68.

Shields, J.D. and C.M. Squyars. 2000. Mortality and hematology of blue crabs, *Callinectes sapidus*, experimentally infected with the parasitic dinoflagellate *Hematodinium perezi*. Fishery Bulletin 98(1): 139-152.

Shields, J.D. 2012. The impact of pathogens on exploited populations of decapod crustaceans. Journal of Invertebrate Pathology 110: 211-224

2013 Chesapeake Bay Blue Crab Advisory Report
CBSAC Meeting Date: May 13th, 2013
Report Final Draft: May 28th, 2013

1. INTRODUCTION

1.1 Background

The Chesapeake Bay Stock Assessment Committee (CBSAC) combines the expertise of state agencies and scientists from the Chesapeake Bay region with that of federal fisheries scientists from the National Marine Fisheries Service 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: 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 (approximately every five years). 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, that 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). Similarly, 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 the NOAA Chesapeake Bay Office, the SFGIT is led by an executive committee of senior fisheries managers from the MD DNR, VMRC, PRFC, the Atlantic States Marine Fisheries Commission (ASMFC), and the District Department of the Environment (DDOE).

CBSAC has adopted the Bay-wide Winter Dredge Survey (WDS) as the primary indicator of blue crab population health 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 around the Bay (Figure 1). The measured densities of crabs are adjusted to account for the efficiency of the sampling gear and are expanded to reflect the area of Chesapeake Bay, providing an annual estimate of the number of over-wintering crabs by age and sex[2].

1.2 Background: Previous and Current Management Framework

A comparison of the current female-specific and previous (both sexes combined) biological reference points for the Chesapeake Bay blue crab fishery is presented in Table 1 (below). The exploitation fraction is the estimated percentage of crabs removed from the population by commercial and recreational fisheries. While this was previously calculated as the removal of both male and female crabs, 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 2013 exploitation fraction cannot be calculated until the completion of the 2013 fishery and is therefore listed as *TBD*. 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 and replaces the previous abundance target and threshold for all age-1+ crabs of both sexes. Management seeks to control the fishery such that the overfishing threshold is not exceeded, resulting in a larger number of crabs than required by the overfished threshold. Ideally, the fishery should operate to meet target values and should never surpass threshold values. Stock status levels that do not exceed threshold values are shown in green.

Control Rule	Reference Points			Stock Status			
	Period	Target	Threshold	2010	2011	2012	2013
Exploitation Fraction	Current, Female-specific	25.5%	34% (max)	18%	25%	10%	**TBD**
	Former, Sexes-Combined	46%	53% (max)	39%	45%	23%	**TBD**
Abundance (millions of crabs)	Current, Female-Specific	215	70 (min)	251	190	97	147
	Former, Sexes-Combined	200	86 (min)	315	254	178	189

(Table 1)

2. CONTROL RULES

2.1 Control Rule from 2011 Benchmark Assessment

The 2011 benchmark assessment recommended a revised control rule based on biological reference points for the female component of the population (Figure 2). 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[7]. 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 Fishery 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 75% N_{MSY} (target) and 50% N_{MSY} (threshold). The annual exploitation is calculated empirically 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. Within 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 estimations to the modeled data.

2.2 Male Conservation Points of Reference

In 2011, CBSAC recommended that in order to ensure that male abundance does not decline to a critical level relative to female abundance, a conservation trigger, based on male abundance, should be explored.

To address these concerns, in 2012, CBSAC suggested a precautionary approach that would maintain the fishery within historical levels of male exploitation and ratios of male to female crabs. This would ensure that the male component of the stock would not become more heavily fished, relative to the female component than we have observed since 1990. These conservation points of reference were identified as a male exploitation fraction not to exceed 66% and a male to female operational sex ratio to be maintained above historical values of 0.57 (meaning the number of mature males to every mature female).

At the 2013 CBSAC Blue Crab Advisory Report meeting, the committee reviewed this previous recommendation and after application to the 2013 WDS results, determined that these points of reference, regressed upon each other, were not biologically meaningful. There is no identifiable relationship between operational sex ratio, as calculated from the WDS, and male exploitation rate.

Accordingly, CBSAC recommends a simpler approach which sets conservation triggers for male crabs based on male exploitation and on the former management framework. Conservation measures, by the management jurisdictions, should be considered for male blue crabs if either of the following occurs:

1) The current male exploitation rate exceeds 62% 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 has occurred in the last 23 years.

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 (53% of crabs, both sexes, Figure 4). The 2012 male exploitation fraction is estimated as 11%.

This fraction is not above the male conservation trigger of 62% male exploitation. The total exploitation rate (23%, both sexes) does not exceed the interim threshold of 53%. No management action is recommended at this time specific to male blue crabs.

3. POPULATION SIZE (ABUNDANCE)

3.1 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 147 million female spawning-age crabs were estimated to be present in the Bay at the start of the 2013 crabbing season (Figure 5). The 2013 estimate of total spawning age female crabs represented a 54.7% increase with respect to the over-wintering population of 97 million in 2012. This number is below the recommended target but remains above the new threshold.

3.2 Exploitable Female Stock – Abundance of Female crabs Aged-0^+

In 2013, the total abundance of female crabs, as measured by the WDS declined 48% to 206.4 million crabs from the 2012 estimate of 400 million crabs (Figure 6). The total population of female crabs forms the basis for the annual calculation of the exploitation rate of female crabs relative to the established target of 25.5% and threshold of 34%. The juvenile component of the female stock is scaled up by a factor of 2.5 when calculating the annual exploitation fraction. The effects of this juvenile scaling factor on total female abundance are directly related to the strength of the year class. When the juvenile scalar is included in the estimation of total female abundance, the exploitable female stock declined 66% from 858 million crabs in 2012 to 296 million crabs in 2012 (Figure 7).

3.3 Age-1+ Male

In 2013, 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 approximately 42 million crabs (Figure 8). This represents a 48% decline in male abundance from 2012.

3.4 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. Without applying the scalar as describe in section 2.1, the estimate of age 0 crabs decreased from 581 million in 2012 to 111 million in 2013 (Figure 9). These estimates are assumed to underestimate the true population as they incorporate neither the vulnerability of juveniles to WDS gear nor the juvenile scalar of 2.5. The recruitment estimate for 2012 was the largest recruitment event recorded in the 24 years of the WDS. The number of recruits observed in the 2013 WDS was substantially lower. CBSAC notes the observed drop in 2013 is within historical bounds of the WDS and is likely a characteristic of natural recruitment variability resulting from blue crab biology.

4. HARVEST

4.1 2012 Commercial and Recreational Harvest

Based on continued evidence of inflated harvest reports, Maryland's 2012 commercial harvest was estimated from fishery-independent data sources including the Maryland commercial reference fleet and an annual survey of crab pot effort in the Maryland portion of Chesapeake Bay[6]. The

2012 Maryland commercial crab harvest from the Bay and its tributaries was estimated as 31 million pounds. Maryland's 2012 reported commercial harvest of 38.7 million pounds was 23% higher than the estimated harvest.

The 2012 commercial harvest in Virginia Chesapeake area was reported to be 21 million pounds, and 3.5 million pounds were reported to have been harvested from the jurisdictional waters of the PRFC (Figure 10). Maryland's 2012 commercial harvest declined 11% from 2011. Commercial harvest in 2012 in Virginia decreased by 26%, while Potomac River remained stable, compared to 2011 levels. Prior to 2008, recreational harvest had been assumed to be 8% of the total Bay wide commercial harvest.[3,4,5] 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. Therefore, 2012 Bay-wide recreational harvest was estimated to be 3.9 million pounds. Combining these categories, approximately 60.0 million pounds were harvested from Chesapeake Bay and its tributaries during the 2012 crabbing season. Despite decreasing by almost 12 million pounds, the 2012 Bay-wide harvest was near the average harvest of the most recent ten years.

4.2 Exploitation Fraction: Reference Points

The percentage of crabs removed by fishing (exploitation fraction) of female (ages 0 and 1+) crabs in 2012 was approximately 10% and well below the target of 25.5% and the threshold of 34% (Figure 6).

When considering the previous reference points, the percentage of male and female crabs removed by fishing (exploitation fraction) was approximately 25%, which is well below the previous (sexes combined) target of 46% and below the previous threshold of 53% (Figure 4).

5. STOCK STATUS

The Chesapeake Bay blue crab stock is currently **not overfished,** and **overfishing is not occurring** (Figure 2). These conclusions remain true under current as well as the former control rule using both sexes. Abundance, harvest, and exploitation of all crabs are summarized in Table 2.

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

The female exploitation fraction in 2012 was below the recommended target of 25.5% for the sixth consecutive year. Although the abundance of adult female crabs has increased in 2013 recruitment was low in 2013 and the exploitable female stock declined by 66%. Additionally, the survival of 2012 recruits seems to have been very poor. Future catches could depend heavily on the survival and successful reproduction of the 2013 age-1^{+} females. CBSAC finds this as further justification for a risk averse and cautious management approach that ensures harvest is adequately constrained relative to abundance.

6.2) Catch Reports

If management based on exploitation fraction continues, the CBSAC recommends that the jurisdictions implement procedures that allow accurate accountability of all commercial and recreational harvest. If the jurisdictions continue with a sex-specific regulatory strategy, CBSAC recommends greater efforts to characterize the biological characteristics of all catch.

6.3) Impacts of 2013 catches on exploitation fraction

The 2013 exploitation fraction that will be reported in next year's CBSAC report will be calculated as the 2013 Bay-wide commercial and recreational harvest of female crabs divided by the exploitable female stock measured in the 2012-2013 WDS. If the 2013 harvest is equal to the 2012 harvest, the 2013 exploitation fraction will be 29%, which is above the target, but below the threshold. To achieve the target exploitation fraction of 25.5%, 2013 harvest levels should be 10% lower than the estimated 2012 harvest.

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 seasonal distribution of crabs, could potentially balance annual harvests with highly variable recruitment events. The CBSAC recommends that jurisdictions evaluate the benefits of quota-based management systems. Allocating annual quotas to each jurisdiction would improve performance of a Bay-wide quota and lead to jurisdictional accountability of harvest relative to the Bay-wide exploitation target.

7.2) Effort Control

The blue crab fishery is currently managed under effort control with limited entry, size limits, catch limits, and seasonal closures as the principal tools. However, the amount of effort expended in the fishery remains poorly quantified. CBSAC recommends an increased investment in Bay-wide effort monitoring that should include actions in all jurisdictions to implement a pot marking system and a bay wide survey of crab pot effort to estimate the total, spatial, and temporal patterns of the crab pot fishery.

7.3) 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 continued efforts be made to estimate and monitor the level and possible re-entry of latent effort into the fishery. In addition to increases in latent effort, CBSAC also recognizes that temporal and seasonal shifts in estimated 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 and better understood as a part of this recommendation.

8. CRITICAL DATA AND ANALYSIS NEEDS

Blue crab management now employs sex-specific regulatory strategies. Given this, the lack of data describing sex ratio and size composition of the harvest will impede efforts to develop effective management strategies. Below, CBSAC has identified the following list of fishery dependent and independent data needs as well as the benefits provided to management. CBSAC is planning on meeting mid July 2013, to begin to discuss the prioritization of the needs identified below as well as the potential investigators, cost and duration of the projects.

8.1 Increased accountability and harvest reporting for both commercial and recreational fisheries: 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.

8.2 Gear efficiency pertaining to selectivity of WDS methods: The WDS survey methods to estimate gear efficiency differ between the two states. CBSAC recommends continuation of a comprehensive comparison between MD and VA WDS methodologies and gear. Following the comprehensive comparison, the accuracy and reliability of current scalars and efficiency corrections should be reevaluated. MD DNR and 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. However, it is anticipated that considerable progress can be made by exchanging assigned sample stations between the two jurisdictions rather than adding new stations. Additional manpower may be required to analyze the results of the comparisons.

8.3 Over-wintering mortality: Examine WDS data to see if there are available data that may better describe overwintering mortality. This data mining exercise could provide CBSAC and managers with a more complete understanding of the variability in natural mortality year to year and potentially improve future assessments. CBSAC recommends that initial efforts be focused on determining a statistical approach to use with existing data that can be developed to provide a more reliable bay wide mortality estimate.

8.4 Recruitment: Based on the results of the 2012-2013 WDS, a large number of recruits disappeared from the stock since the 2011-2012 WDS. Based on the stock assessment and pilot field experiments by VIMS and the Smithsonian Environmental Research Center, a large fraction of juveniles in shallow water is not sampled by the WDS. For the former, CBSAC recommends analyzing pertinent environmental and ecological variables to erect and examine potential hypotheses to explain the poor survival of this record recruitment event. Anticipated time to completion is three to four months. 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.

8.5 Investigation of the potential for sperm limitation: CBSAC recommends an analysis of 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. This data mining project is of high priority as the potential for sperm limitation would first be observed by analyzing the proportion of second and third year females in the WDS results. From this discussion, CBSAC has identified that this analysis could be completed from existing WDS data and would require only staff time to support further analysis.

8.6 Operational sex ratio: There is no identifiable relationship between operational sex ratio, as calculated from the WDS, and male exploitation rate. Furthermore, CBSAC decided that the WDS abundance data are unsuitable for representing the Bay-wide operational sex ratio, and a summer month survey would provide a more accurate depiction. CBSAC recommends that this summer survey should be explored.

8.7 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.

8.8 Collaborative Bay-wide fishery independent survey: A collaborative and coordinated Bay-wide, 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
Lynn Fegley	Maryland Department of Natural Resources
Derek Orner	NOAA Chesapeake Bay Office
Tom Miller	UMCES, Chesapeake Biological Laboratory
Daniel Hennen	NMFS, Northeast Fisheries Science Center
Alexei Sharov	Maryland Department of Natural Resources
Rob O'Reilly	Virginia Marine Resource Commission
Mike Seebo	Virginia Institute of Marine Science
John Hoenig	Virginia Institute of Marine Science
Rom Lipcius	Virginia Institute of Marine Science
Amy Schueller	NMFS, Southeast Fisheries Science Center
Eric Johnson	University of North Florida
Glenn Davis	Maryland Department of Natural Resources
Allison Watts	Virginia Marine Resources Commission
John McConaugha	Old Dominion University

CBSAC Coordinator:

Andrew Turner	NOAA Chesapeake Bay Office/Versar

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. 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.

4. 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.

5. 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.

6. Barker, L.S., Davis, G.R., Fegley, L.W. 2009. Estimation and Verification of the 2008 Maryland Chesapeake Bay Blue Crab Harvest. A Report for the Chesapeake Bay Stock Assessment Committee (CBSAC).

7. 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.

8. Miller, T. J. et al. 2005. Stock Assessment of the Blue Crab in Chesapeake Bay. Technical Report Series No. TS-487-05 of the University of Maryland Center for Environmental Science, 162p.

9. Fegley, L.W. 2007. Analyses toward establishing an age 1+ target abundance for the Chesapeake Bay Blue Crab. A Report for the Chesapeake Bay Stock Assessment Committee (CBSAC).

10. Chesapeake Bay Stock Assessment Committee. 2008. Chesapeake Bay Stock Assessment Committee 2008 Blue Crab Advisory Report, Appendix 1. Working Meeting on Blue Crab Assessment and Management. January 27, 2008. NOAA Chesapeake Bay Office. Annapolis, Md.

Table 2. 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 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		

* 2012 Bay-wide commercial harvest and exploitation rate are preliminary.

Figure 1. Winter dredge survey index of total blue crab abundance (density of males and females, all sizes combined) in Chesapeake Bay, 1990 through 2013. Error bars represent 95% confidence intervals.

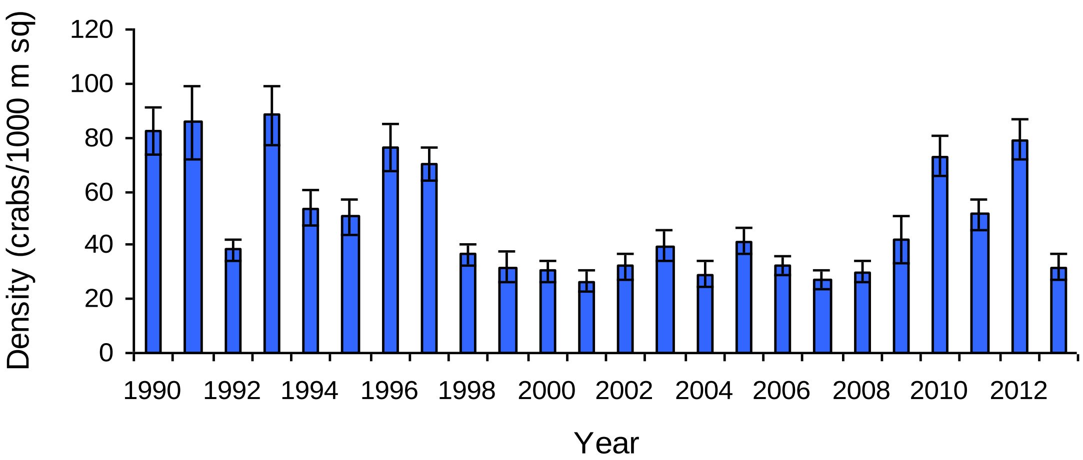


Figure 2. The female-specific control rule for the Chesapeake Bay blue crab fishery. In 2012, abundance was below the overfished target, while the exploitation rate was below the overfishing target. Reference points were derived from a statistical assessment model incorporating multiple surveys.

Exploitation: target is 25.5%, threshold is 34%

Abundance: target is 215 million crabs, threshold is 70 million crabs

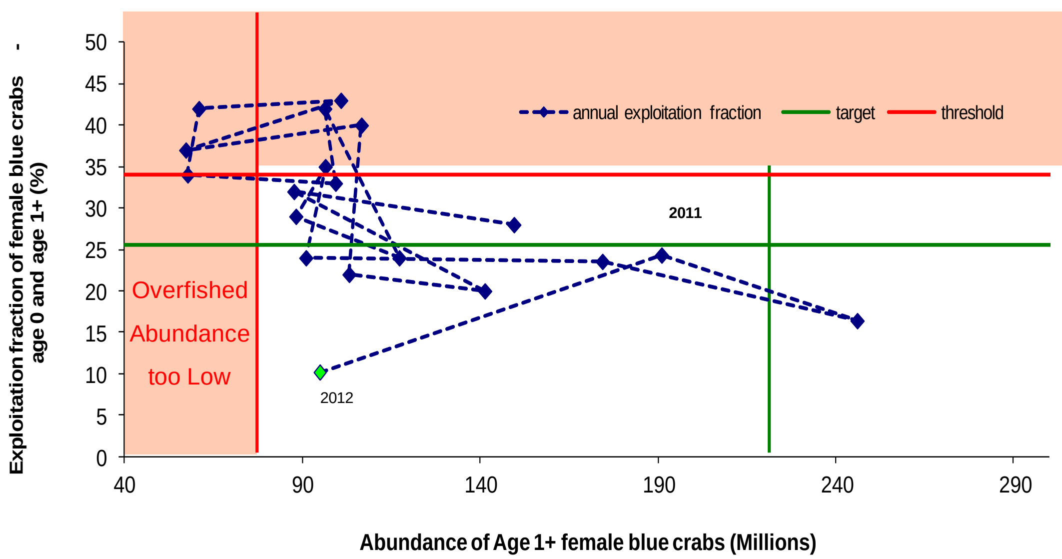


Figure 3. One of two male-specific triggers for the Chesapeake Bay blue crab fishery. The percentage of male crabs removed from the population each year by fishing, 1990 through 2012. Exploitation rate (% removed) is the number of male crabs harvested within a year divided by the male population estimate (age 0 and age 1+) at the beginning of the year.

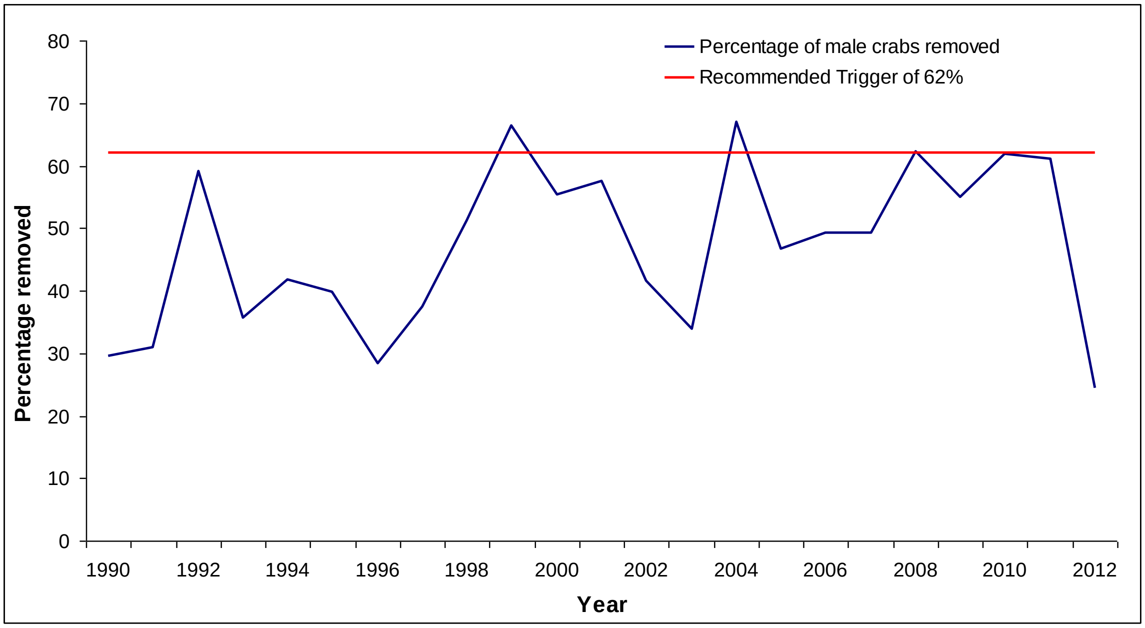


Figure 4. One of two male-specific triggers for the Chesapeake Bay blue crab fishery. The percentage of male and female crabs removed from the population each year by fishing relative to previously used target (46%) and threshold (53%) exploitation rates, 1990 through 2012. Exploitation rate (% removed) is the number of crabs harvested within a year divided by the population of all crabs estimate at the beginning of the year.

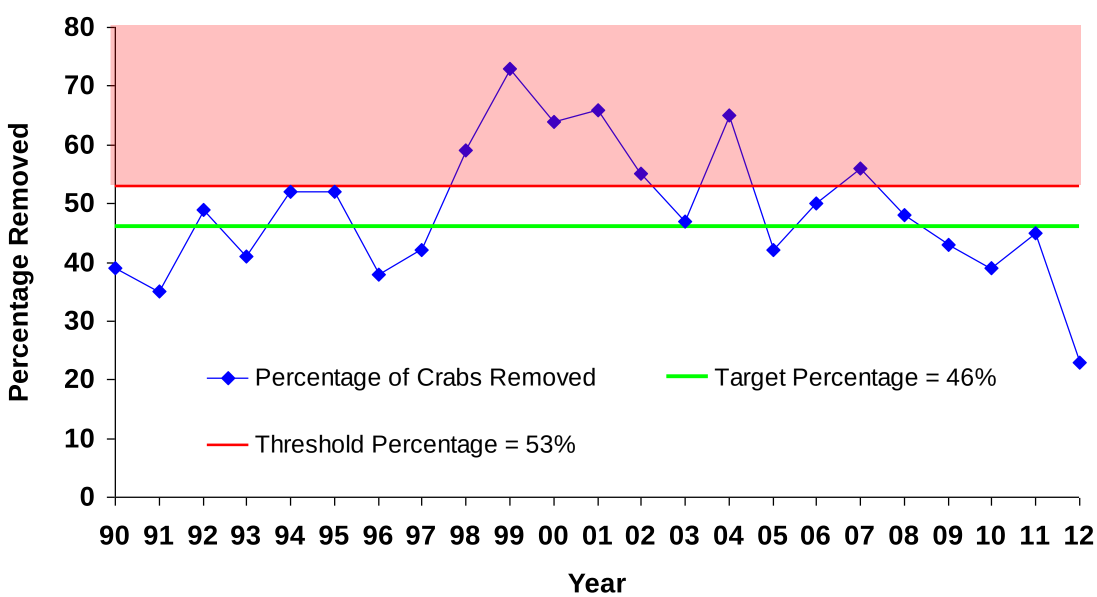


Figure 5. Winter dredge survey estimate of **abundance of female blue crabs age one year and older** (age 1+) 1990-2013 with female-specific reference points. These are female crabs measuring greater than 60mm across the carapace and are considered the 'exploitable stock' that will spawn within the coming year.

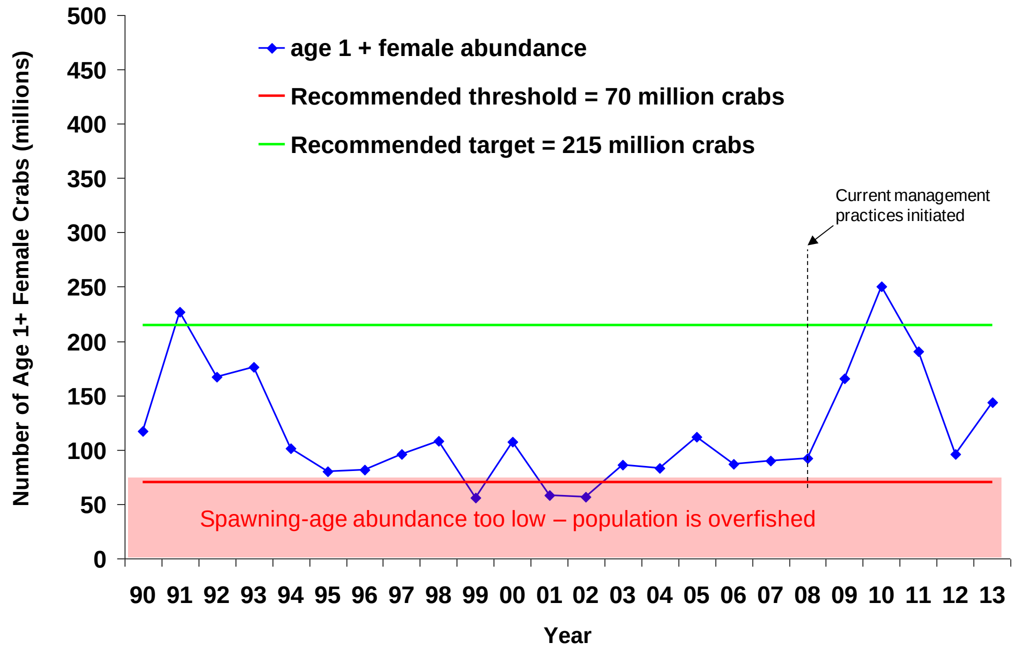


Figure 6. The percentage of female blue crabs removed from the population each year by fishing relative to the female-specific target (25.5%) and threshold (34%) exploitation rates, 1990 through 2012. Exploitation rate (% removed) is the number of female crabs harvested within a year divided by the female population (age 0 and age 1+) estimated at the beginning of the year.

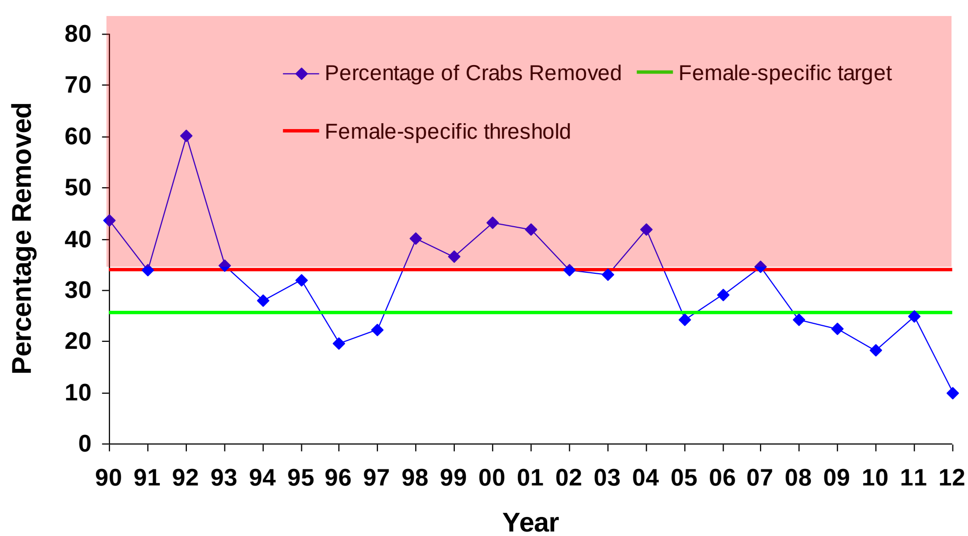


Figure 7. Winter dredge survey estimate of **abundance of all female blue crabs (age 0 and age 1+ combined)** 1990-2013. This estimate includes a catchability scalar for juvenile blue crabs, and is the basis of female exploitation rate calculations. Error bars represent 95% confidence intervals.

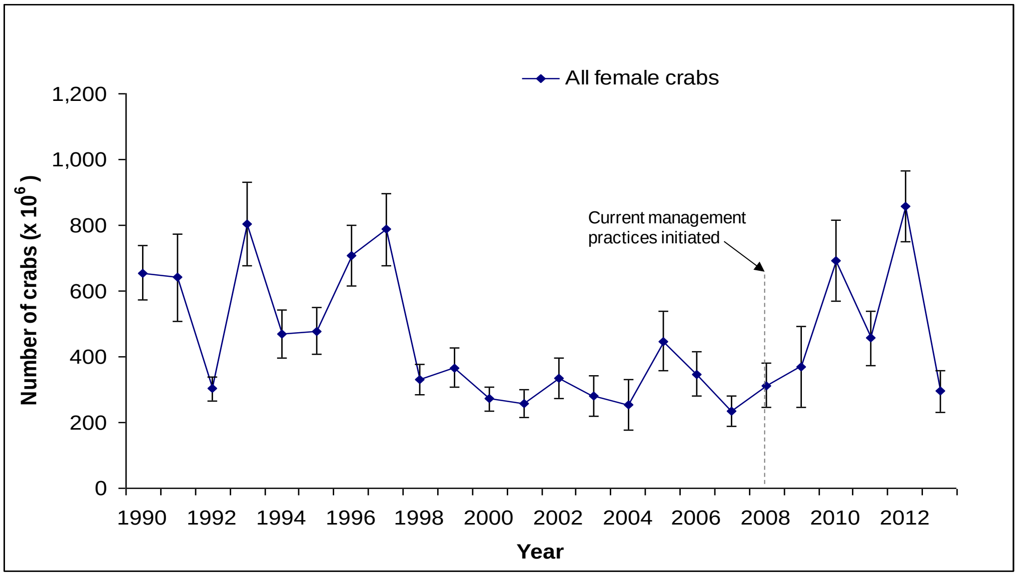


Figure 8. Winter dredge survey estimate of **abundance of male blue crabs age one year and older (age 1+)** 1990-2013. These are male crabs measuring greater than than 60mm across the carapace and are considered the 'exploitable stock' capable of mating within the coming year. Error bars represent 95% confidence intervals.

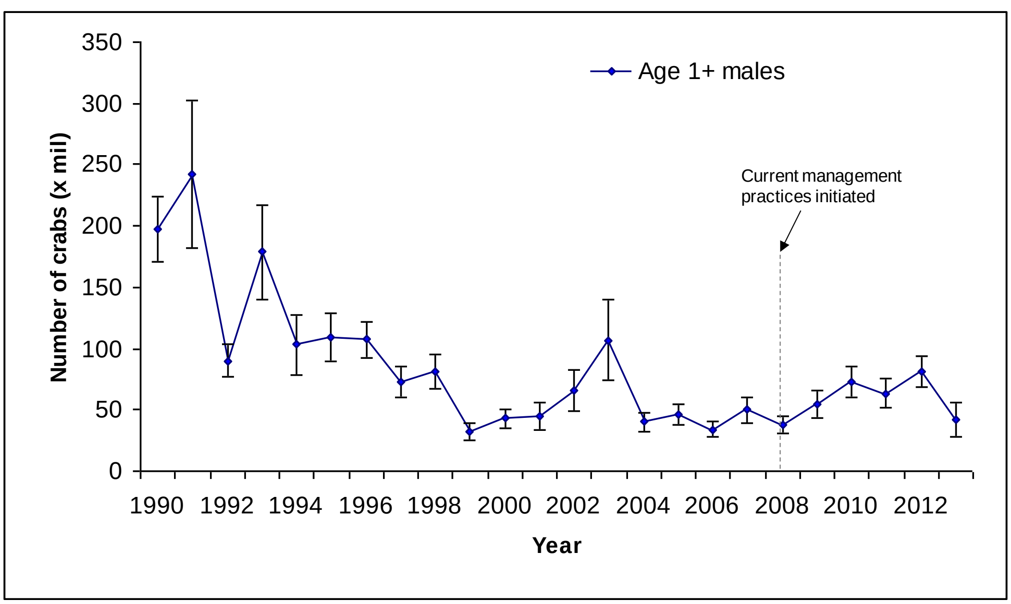


Figure 9. Winter dredge survey estimate of **abundance of juvenile blue crabs (age 0)**, 1990-2013. These are male and female crabs measuring less than 60mm across the carapace. Error bars represent 95% confidence intervals.

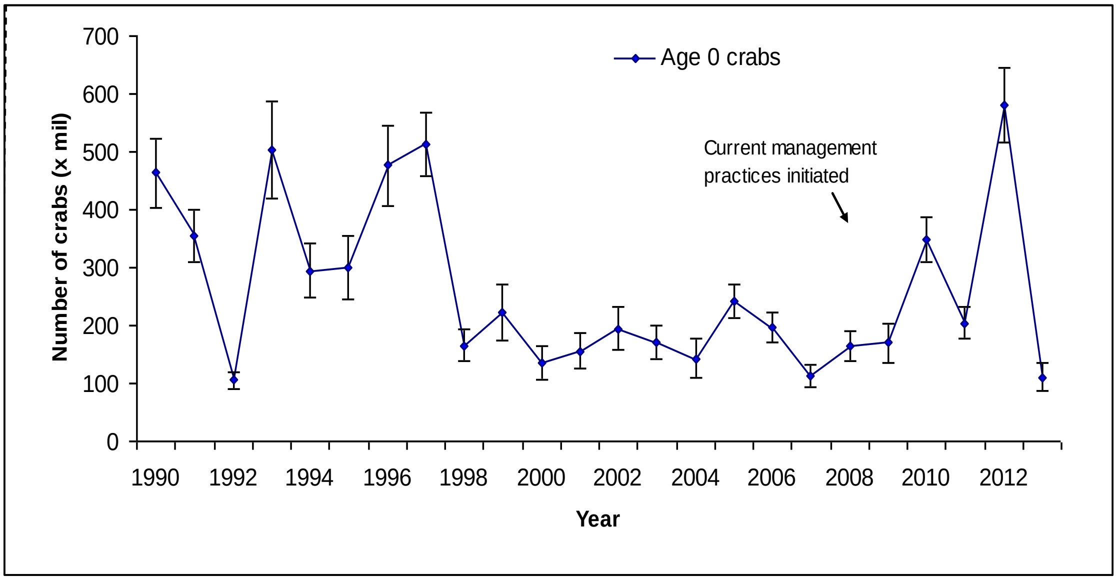
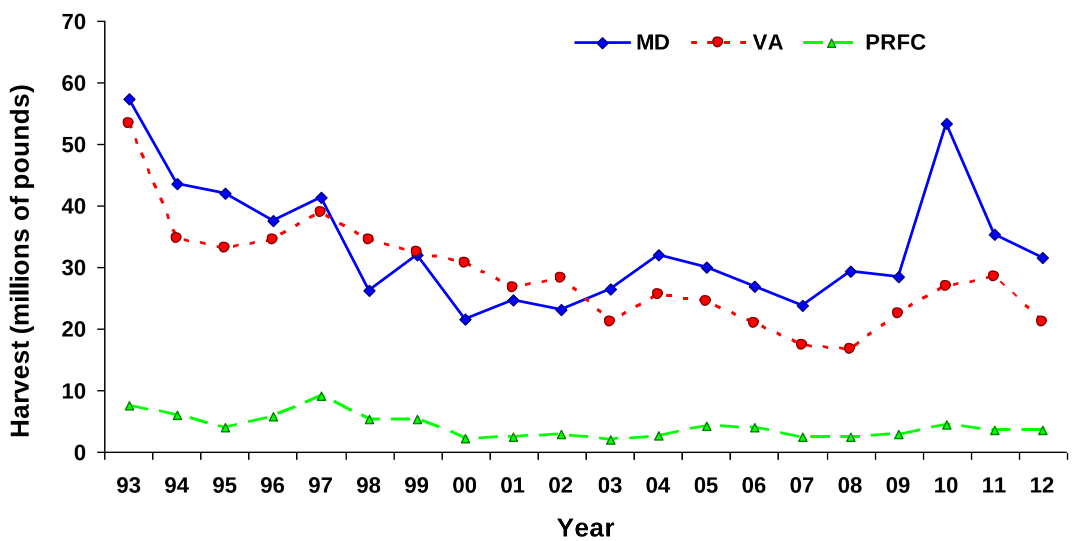


Figure 10. Maryland , Virginia and PRFC Chesapeake Bay commercial blue crab harvest in millions of pounds, 1993-2012.



VIRGINIA 'S 21 -POINT BLUE CRAB MANAGEMENT PLAN

October 1994, the Commission established the following 7-point blue crab management plan:

- Expanded the spawning sanctuary (146 sq. mi.) establish in 1942 by 75 sq. mi., with no crab harvest allowed from June 1 through September 15.
- Established a 14,500-acre winter-dredge sanctuary in Hampton Roads.
- Shortened the crab pot season to April 1 through November 30.
- Required two cull (escape) rings in each commercial and recreational crab pot.
- Required four cull rings in each peeler pound that allows escapement of small peeler crabs.
- Capped the number of peeler pots per license to prevent expansion of the fishery.
- Limited the crab dredge size to 8 feet to prevent increases in effort.

The Commission reinforced the 7-point management plan in January 1996.

- Prohibited the possession of dark-colored (brown through black) sponge crabs (adult female hard crab which had extruded her eggs on her abdomen), with a 10-sponge crab per bushel tolerance.
- Limited license sales of hard crab licenses, based on previous eligibility or exemption requirements.
- Established a 300-hard crab pot limit for all Virginia tributaries of the mainstem Chesapeake Bay. Other Virginia harvest areas were limited to a 500-hard crab pot limit.
- Established a 3 1/2-inch minimum possession size limit for all soft shell crabs.

Concerns over excess effort in the fisheries and a persistent trend of low spawning stock biomass during most of the 1990's led to additional crab conservation measures in 1999 and 2000.

- Lowered the maximum limit on peeler pots from 400 to 300 pots in 1999. Harvest by this gear type increased by 90%, from 1994 through 1998, while the overall harvest remained relatively static.
- Initiated a moratorium on additional commercial licenses for all commercial crabbing gear. This moratorium became effective May 26, 1999 and continued until May 26, 2004.
- Established (in 2000) a Virginia Bay-wide Blue Crab Spawning Sanctuary, in effect June 1 through September 15. This additional sanctuary (435 sq. mil) allows for increased spawning potential.

A cooperative Bay-wide agreement (October 2000) to reduce harvest 15% by 2003 led to new measures.

- Enacted an 8-hour workday for commercial crabbers (2002) that replaced Wednesday closures of 2001.
- Established a 3-inch minimum size limit for peeler crabs (2002).
- Reduced peeler pot limits from 400 to 300 pots (for 2001).
- Reduced the winter dredge fishery limit from 20 to 17 barrels (2001).
- Augmented (2002) the Virginia Blue Crab Sanctuary by 272 sq. mi. (total sanctuary area = 928 sq. mi.).
- Reduced unlicensed recreational harvester limits to 1 bushel of hard crabs, 2 dozen peelers (2002).
- Reduced licensed recreational harvester limits to 1 bushel of hard crabs, 2 dozen peelers, with vessel limit equal to number of crabbers on board multiplied by personal limits (2001).

ACTIONS TO PROMOTE REBUILDING OF CHESAPEAKE BYA BLUE CRAB STOCK (2008 through 2013)

February 2008

- Larger cull ring (2-5/16") required to be open at all times in all tidal VA waters to promote additional increases in escapement
- Peeler crab minimum size limit increased from 3" to 3 ¼" (through July 15) and to 3 ½" (as of July 16)
- Use of agents modified to prevent license "stacking" and to curtail use of agents
- Winter dredge fishery capped at 53 licensees (from previous 225 licensees), all being active harvesters in previous two winter seasons

March 2008

- Adopted an extended closure (May 1 - September 15) of blue crab spawning sanctuary, to protect spawning females, except for the historical sanctuary (146 square miles) managed by law

April 2008

- Established a fall closure for female harvest (October 27 – November 30)
- Implemented a 15% reduction in pots per individual for 2008 crab pot fishery and a 30% reduction for 2009 crab pot and peeler pot fishery
- Closed 2008/09 winter dredge fishery season
- Required use of two 3/8" cull rings for all areas (except Seaside of Eastern Shore) effective July 1
- Eliminated 5-crab pot recreational license
- Revamped revocation procedures, to allow a hearing after just two crab violations in a 12-month period

November 2008

- In an attempt to address the latent effort, the Commission placed crab pot and peeler pot fishermen who had been inactive (no harvest) for a 4-year period (2004-07) on a waiting list until the abundance determined from the Bay-wide Winter Dredge Survey of age-1+ crabs exceeds the interim target of 200 million

May 2009

- Shortened closed season for female crabs to November 21 - November 30
- Closed 2009/10 winter dredge fishery season
- Lowered percentage reduction of crab pots from 30% (2008) to 15% (2009)
- Reestablished 5-pot recreational crab pot license but prohibited harvest on Sunday and from Sept 16 - May 31
- Right to hold revocation hearing for crab licensee after two crab violations by authorized agent (agents cannot be licensed for any crab fishing gear)
- regulation tolerance of 10 per bushel (Previously March 17 – July 15)

May 2010

- Made it unlawful (from March 17 - June 30) to possess dark sponge crabs exceeding regulation tolerance of 10 per bushel (Previously March 17 – July 15)
- Made it lawful (indefinitely) that commercial licenses (crab/peeler pot, scrape, trap, ordinary/patent trot line, dip net) shall be sold only to commercial fishermen eligible in 2010, except those placed on the waiting list established in November 2007

- Closed 2010/11 winter dredging fishery season

April 2011

- Changed closed season on harvest from Virginia Blue Crab Sanctuaries from May 16 to May 1
- Changed boundary line of Blue Crab Sanctuary in upper Bay near Smith Point Light

September 2011

- Closed 2011/12 winter dredging fishery season
- Established 5-day maximum tending requirement for crab pots and peeler pots

November 2012

- Closed 2012/13 winter dredge fishery season
- Funded the Winter Dredge Gear Study using Marine Fishing Improvement Funds
- Extended the 2012 season until December 15, 2012 for both male and female crabs and applied conservation equivalent bushel limits to the 2013 crab pot season by gear license categories as follows:
    - For up to 85 crab pots a maximum limit of 27 bushels.
    - For up to 127 crab pots a maximum limit of 32 bushels.
    - For up to 170 crab pots a maximum limit of 38 bushels.
    - For up to 255 crab pots a maximum limit of 45 bushels.
    - For up to 425 crab pots a maximum limit of 55 bushels.
- Restricted crabbing in the Virginia portion of the Albermarle and Currituck watersheds to crab pots and peeler pots only

February 2013

- Established a vessel harvest and possession limit equal to only one of the largest legal bushel limits on board any vessel
- Limited the use of agents in the hard pot fishery to 168, with priority going to those licensees who received approval for agent use in 2012

June 2013

- Established daily individual and vessel harvest and possession limits for the 2013 season

October 2013

- Closed 2013/14 winter dredge fishery season
- Results of the Winter Dredge Mortality Project were presented
- Extended the 2013 season until December 15, 2013 for both male and female crabs and applied conservation equivalent bushel limits to the 2013 season extension and the 2014 crab pot season by gear license categories as follows:
    - For up to 85 crab pots a maximum limit of 16 bushels.
    - For up to 127 crab pots a maximum limit of 21 bushels.
    - For up to 170 crab pots a maximum limit of 27 bushels.
    - For up to 255 crab pots a maximum limit of 43 bushels.
    - For up to 425 crab pots a maximum limit of 55 bushels.
- Established the 2014 crab pot season as March 17 through November 30, 2014 for both male and female blue crabs
- Established a declaration date for agent use requirements in the crab pot fishery for the 2014 season

BLUE CRAB DREDGE MORTALITY PROJECT FINAL REPORT

Romuald N. Lipcius[a,c], Danielle McCulloch[b,c], and Michael S. Seebo[b,c]

8 August 2013

a. Principal Investigator b. Marine Scientist

c. Virginia Institute of Marine Science, College of William & Mary, PO Box 1346, Gloucester Point, VA 23062 USA

WILLIAM & MARY

VIMS

VIRGINIA INSTITUTE OF MARINE SCIENCE

SCHOOL OF MARINE SCIENCE

Contents

1. Introduction

Mr. Robert O'Reilly, Chief of the Fisheries Management Division of the Virginia Marine Resources Commission (VMRC), requested on behalf of Commissioner Jack Travelstead that we conduct a field experiment on incidental mortality in the blue crab winter dredge fishery (Appendix 1). As requested by Mr. O'Reilly, the objective of the experiment was to assess, at a minimum, the influence of bottom sediment type and temperature on the relative extent that crabs are damaged by the dredge gears. The methodology that was used to guide this experiment was based on the discussions of a panel over the course of several meetings, including VIMS, VMRC, members of the Crab Dredge Subcommittee of VMRC, and four crabbers selected as crab dredge captains to conduct the field study.

2. Methods

This study was conducted from 20 December 2012 to 15 March 2013 by VIMS staff, VMRC staff and four commercial dredging captains. Captains were selected from a volunteer pool based on experience, vessel quality and condition, and safety preparedness. Each participating vessel was equipped with two commercial crab dredges, dredging gear, a depth sounder, a GPS chart plotter, and a CB radio.

VIMS staff scheduled field days based on weather conditions, and boarded one of the four participating vessels on all sampling days. VMRC observers boarded a second vessel. All four vessels dredged as a team to scout out high crab density areas on designated bottom types. After approving a sampling area, a buoy was set to mark the site (Appendix Figure 1). A second buoy was set 200 m away from the first buoy, and perpendicular to tow direction. A ponar grab was set overboard to collect sediment samples and to verify bottom type next to each buoy. A YSI meter was used to measure salinity, temperature and dissolved oxygen at each site. After recording all bushel and damaged crab counts from scouting, pre-trial tows were initiated.

Six standardized pre-trial tows were conducted to assess each site prior to dredging impact. Dredges equipped with divers were dragged for 1 min between the buoys, six times, equally in each direction. Each pre-trial tow began once the dredge had set on the bottom, approximately 50 m from the buoys, and ended after 1 min, when the dredge was released from the bottom. Start and end time, start and end coordinates, minimum and maximum depth, vessel speed and direction were recorded for each tow. Once a tow was complete, one of the two dredges was randomly selected for sampling. All captured crabs, bycatch, and dredge contents were placed in bushel baskets and labeled with the respective tow number for processing.

All bycatch was identified and all dredge content volumes were estimated for each pre- trial tow sample. For each blue crab, we determined gender (male or female), maturity (mature or juvenile), and damage. Crabs that were missing carapaces, cut in half, or had deep punctures were categorized as damaged (= discard mortality). Crabs that had small carapace cracks or nicks were considered marketable. Each crab carapace was measured, spine to spine, using calipers. Crabs to be measured were randomly sub-sampled from the full catches.

All vessels were instructed to remove or add dredge divers for impact tows upon the completion of the pre-trial tows. Though each impact tow was made between the boundary buoys, captains adjusted distance, direction, and speed to their preference. This liberty ensured that impact tows effectively mimicked commercial dredging practices. Each vessel made a minimum of five impact tows (at least 20 tows total) at each site. Impact tows continued until captains collectively decided that the area had been depleted substantially.

All vessels reported the total number of bushels caught and total discard mortality to VIMS staff. The staffed vessel then proceeded to complete six standardized post-trial tows, for which pre-trial tow protocol was followed. After six standardized post-trial tows were completed, all vessels began scouting for a new sampling area. New study areas were set at least 0.5 km to either side upstream, and at least 1 km downstream away from previous study areas to ensure that the impact from one study site did not influence the results of subsequent trials. At the end of the day, all GPS tracks were saved, summary totals were recorded, and datasheets/staff vessel log book were completed.

3. Results and Discussion

In the standardized pre-trial tows, the sample sizes were 114 for sand bottom and 132 for mud bottom. In the standardized post-trial tows, the sample sizes were 54 for sand bottom with divers, 60 for sand bottom without divers, 78 for mud bottom with divers, and 54 for mud bottom without divers. At each site there were 6 tows pre-trial and 6 tows post-trial, all of which were deemed independent because of the relatively large sampling area, which precluded resampling of the same location. These relatively high sample sizes allowed us to be confident in the results of the statistical analyses, which were conducted using General Linear Models (GLMs) in the open-access statistical software package R. The data were analyzed as the raw data rather than transformed data because the large sample sizes made the GLMs robust with regards to statistical assumptions.

Dependent variables included the (i) total number of crabs caught per tow, (ii) number of damaged crabs caught per tow, and (iii) proportion of damaged crabs per tow. Independent variables and factors included (i) water temperature, (ii) water depth, (iii) bottom type (sand, mud), and (iv) use of dredge divers (divers, no divers).

To determine whether or not water temperature and water depth affected the dependent variables, we summed the data for the 6 tows per site to generate a single value per site because the measurements of temperature and depth were also a single value for each site. The GLM was run separately for pre-trial and post-trial data.

Water temperature did not significantly ($p >> 0.05$) affect any of the dependent variables, either in pre-trial data (Figure 1) or in post-trial data (Figure 2). Water depth also did not significantly ($p >> 0.05$) affect any of the dependent variables, either in pre-trial data (Figure 3) or in post-trial data (Figure 4). Consequently, we did not include water temperature and water depth in subsequent analyses.

We used bottom type (sand or mud) as a factor in the analysis. To validate the designation, we compared the grain size composition of replicate samples taken at each site relative to the designation as sand or mud. The GLM of grain size composition only used % Sand as the dependent variable because the other components (% Silt, % Clay, % Gravel) covaried with % Sand. The designations of sand bottom or mud bottom for each site were validated by the grain size analysis. The % Sand at designated sand sites averaged over 80% Sand, which was significantly higher ($p < 0.05$) than that at sites designated as mud bottom, which averaged less than 30% Sand (Figure 5).

To determine the effects of bottom type and presence or absence of divers on the dependent variables, we used each of the 246 tows as individual values because they were taken sufficiently distant from each other, such that they could be considered independent samples.

In the standardized pre-trial tows, all of which used divers, the total number of crabs caught per tow (Figure 6), the number of damaged crabs per tow (Figure 7), and the percentage of damaged crabs per tow (Figure 8) were significantly higher ($p < 0.05$) in sand than in mud. On average, there were about 106 total crabs per tow in sand, and 54 in mud (Figure 6). The number of damaged crabs per tow averaged 14 in sand, and only 1 in mud (Figure 7). Consequently, the percentage of damaged crabs per tow was 13.1% on sand bottom, and 1.6% on mud bottom (Figure 8).

In the standardized post-trial tows, all of which used divers, the data reflected the effects of the standardized tows as well as the impact of the dredgers prior to the post-trial tows. Similar to the pre-trial results, the total number of crabs caught per tow (Figure 9), the number of damaged crabs per tow (Figure 10), and the percentage of damaged crabs per tow (Figure 11) were significantly higher ($p < 0.05$) in sand than in mud. In addition, the use of divers also significantly increased ($p <0.05$) all three dependent variables, though the magnitude of the effect differed by bottom type(Figures 9-11).

On sand bottom there was nearly a three-fold increase (173%) in average total crabs caught for tows with divers (65.8 crabs/tow) than for tows without divers (24.1 crabs/tow), whereas on mud bottom tows with divers increased the catch 24% from 33.2 crabs/tow without divers to 41.1 crabs/tow with divers (Figure 9). Note that the post-trial values include the effects of the standardized tows as well as the dredging impact. The individual effect of dredging impact will be made obvious when comparing the percentage of damaged crabs in pre-trial tows and post-trial tows.

The number of damaged crabs per tow on sand bottom increased by 351% when divers were used, from 4.9 crabs/tow without divers to 22.1 crabs/tow with divers (Figure 10).

In contrast, the number of damaged crabs on mud bottom only increased from an average of much less than 1 crab/tow (0.07 crabs/tow) without divers to approximately 1 crab/tow (1.05 crabs/tow) with divers (Figure 10). Again, note that the post-trial values include the effects of the standardized tows as well as the dredging impact. As stated above, the individual effect of dredging impact will be made obvious when comparing the percentage of damaged crabs in pre-trial tows and post-trial tows.

The percentage of damaged crabs per tow in post-trial samples on sand bottom was 27.9% with divers and 19.7% without divers (Figure 11), reflecting a 42% increase through the use of divers. On mud bottom, the percentage of damaged crabs was 4.2% with divers and 0.5% without divers (Figure 11). To distinguish the dredging impact from the standardized post-trial tows, we subtracted the pre-trial values (Figures 8) from the post-trial values (Figure 11). This calculation yields an estimated dredging impact over 1 day as effectively 0% on mud bottom without divers, 4.2% post-trial - 1.6% pre-trial = 2.6% on mud bottom with divers, 19.7% post-trial - 13.1% pre-trial = 6.6% on sand bottom without divers, and 27.9% - 13.1% = 14.8% on sand bottom with divers.

To minimize discard mortality of blue crabs in the winter dredge fishery, were it to be reinstated, dredging would preferably be conducted on mud bottom without divers.

4. Figures

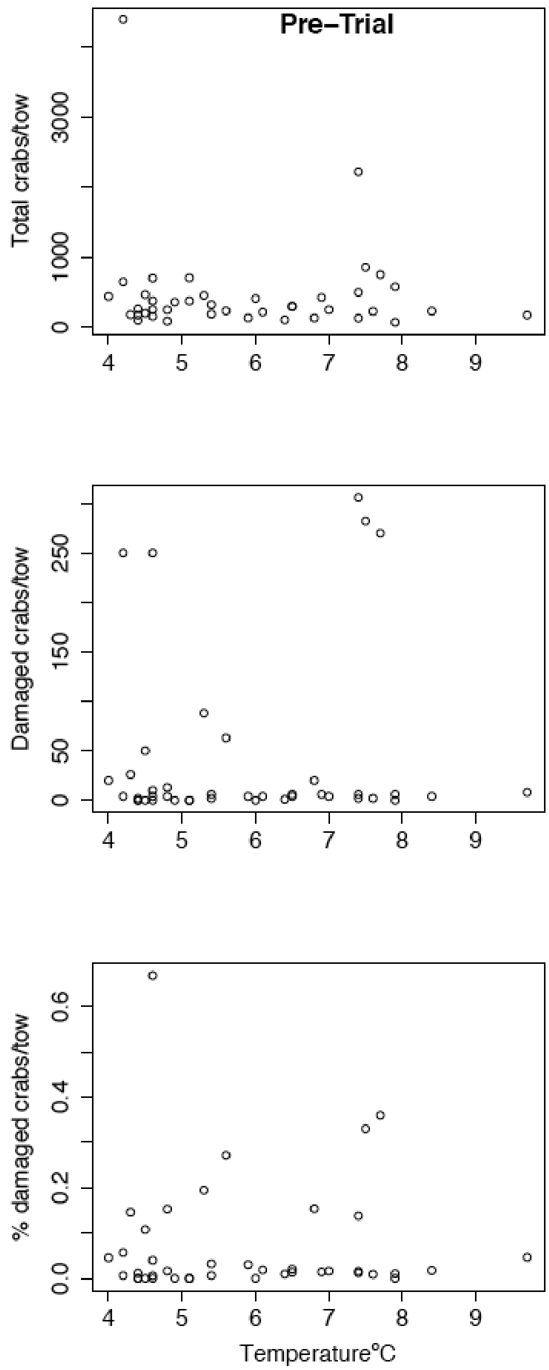


Figure 1: Water temperature did not significantly ($p >> 0.05$) affect crab catch/tow, damaged crabs/tow, and % damaged crabs/tow in standardized pre-trial surveys.

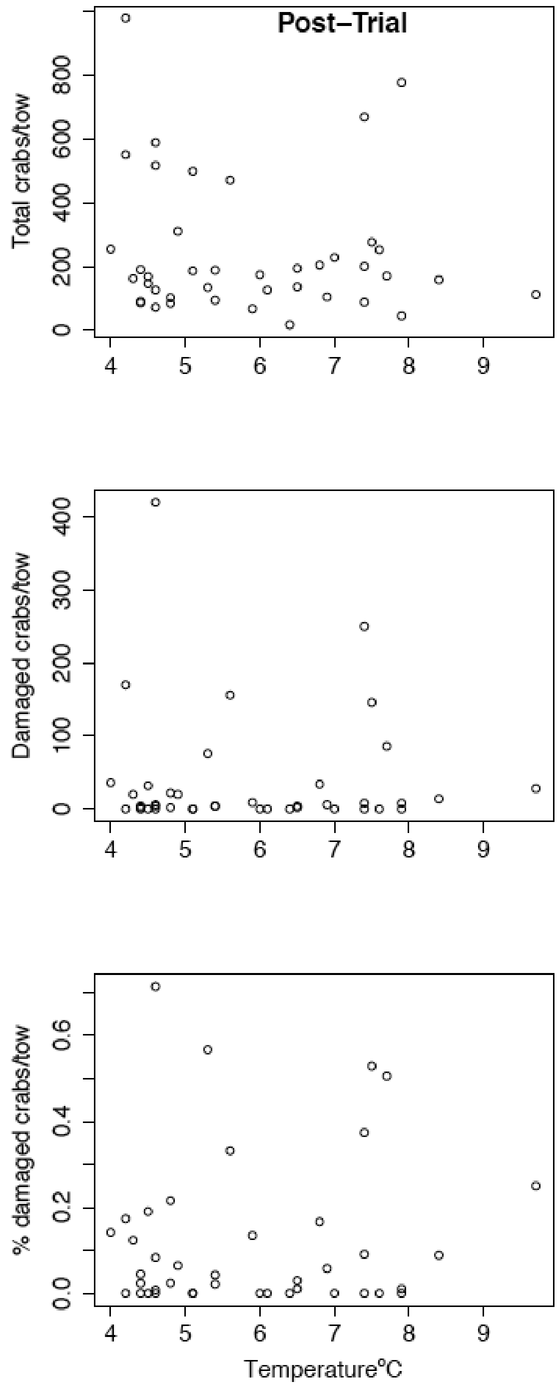


Figure 2: Water temperature did not significantly ($p >> 0.05$) affect crab catch/tow, damaged crabs/tow, and % damaged crabs/tow in standardized post-trial surveys.

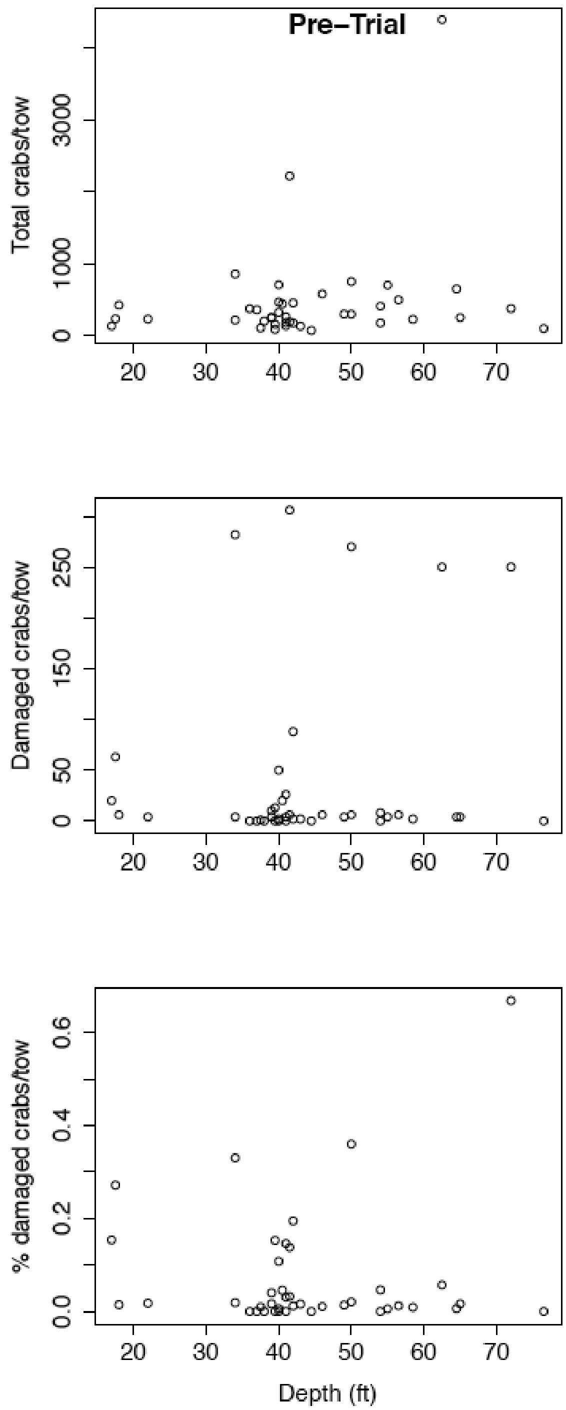


Figure 3: Water depth did not significantly (p >> 0.05) affect crab catch/tow, damaged crabs/tow, and % damaged crabs/tow in standardized pre-trial surveys.

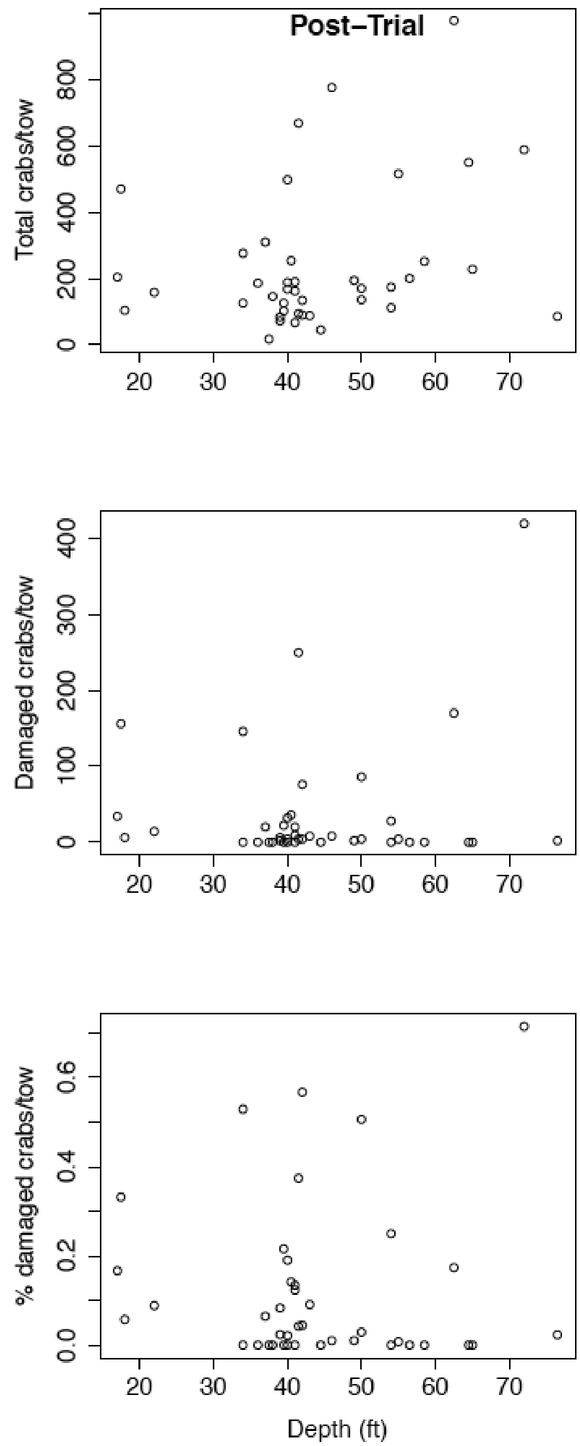


Figure 4: Water depth did not significantly ($p >> 0.05$) affect crab catch/tow, damaged crabs/tow, and % damaged crabs/tow in standardized post-trial surveys.

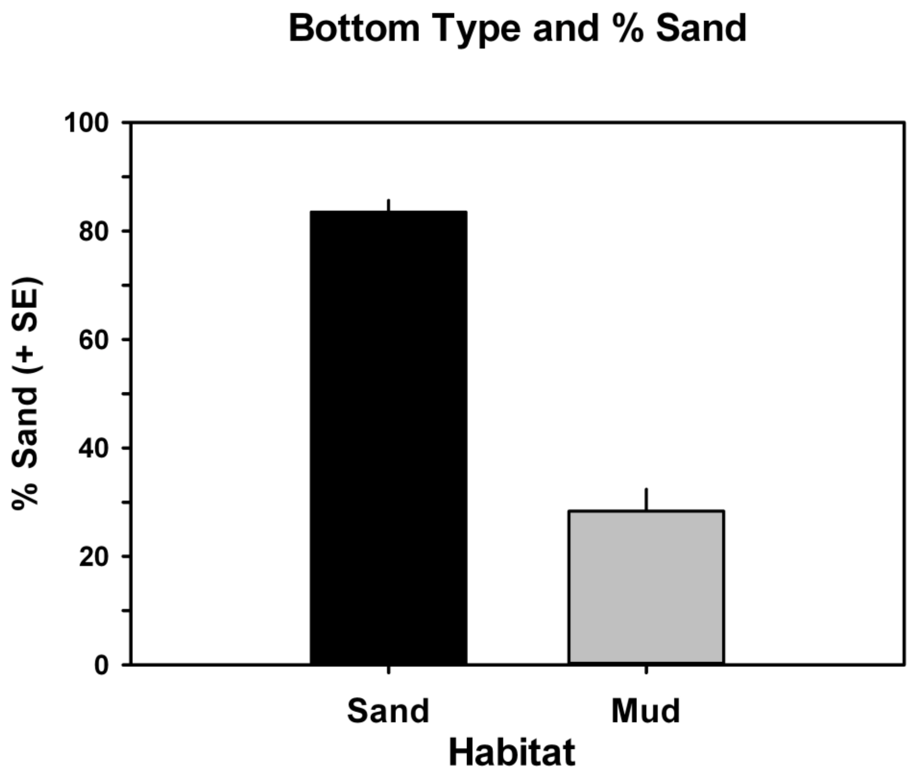


Figure 5: Grain size analysis validated the designation of sites as primarily sand (hard bottom) or mud (soft bottom). The % sand was significantly higher ($p < 0.05$) in sand sites than in mud sites.

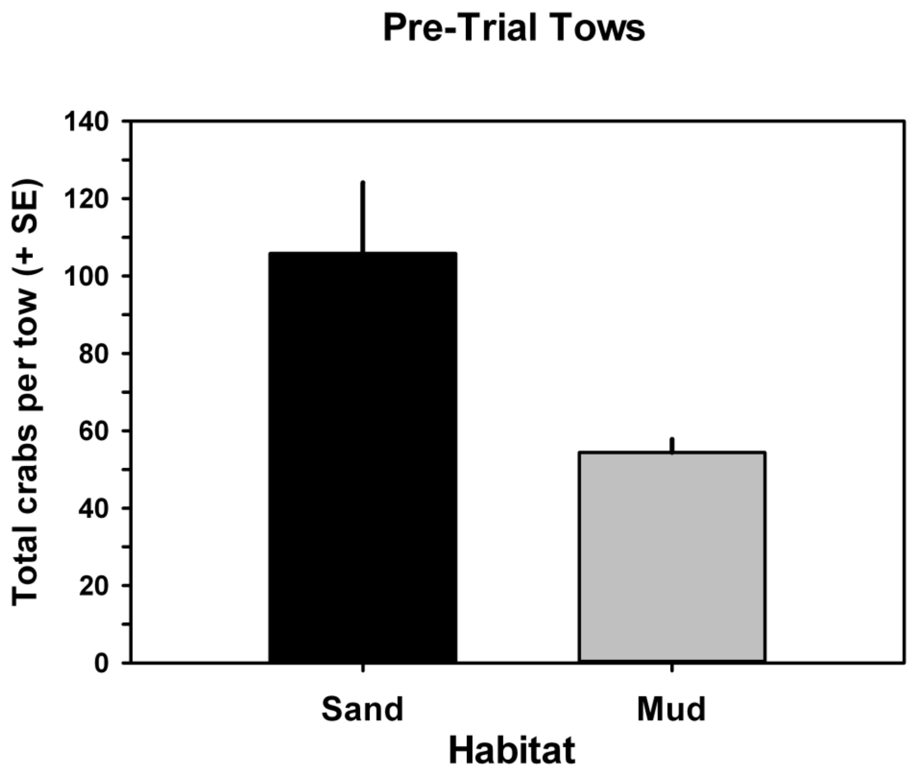


Figure 6: In pre-trial standardized tows, the total number of crabs caught per tow was significantly higher ($p < 0.05$) in sand than in mud. Note that divers were used in all standardized tows.

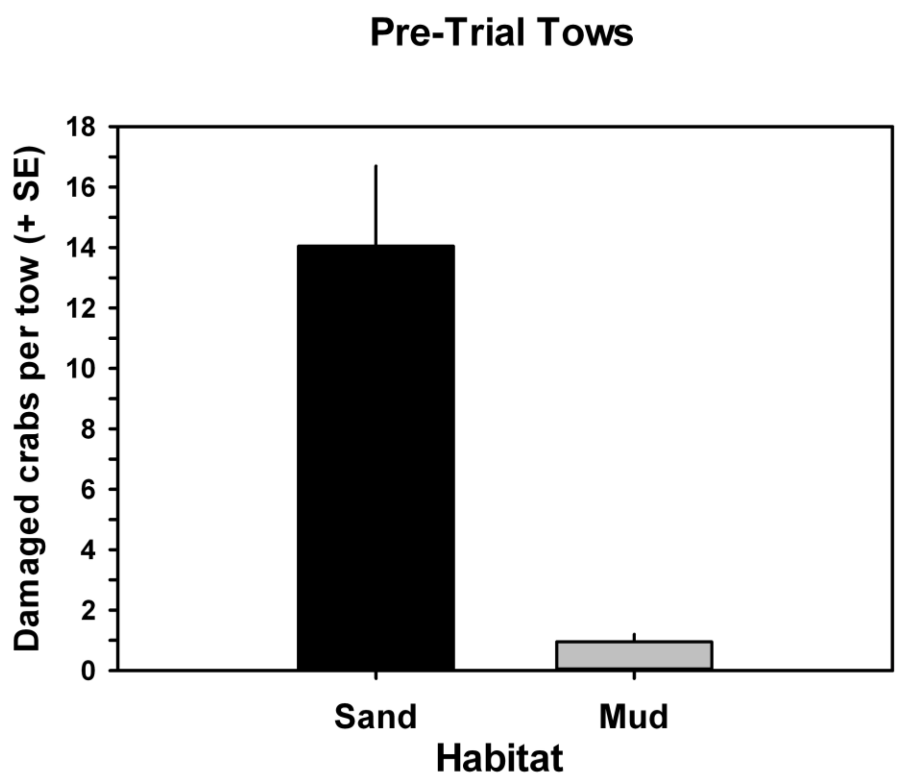


Figure 7: In pre-trial standardized tows, the number of damaged crabs caught per tow was significantly higher ($p < 0.05$) in sand than in mud. Note that divers were used in all standardized tows.

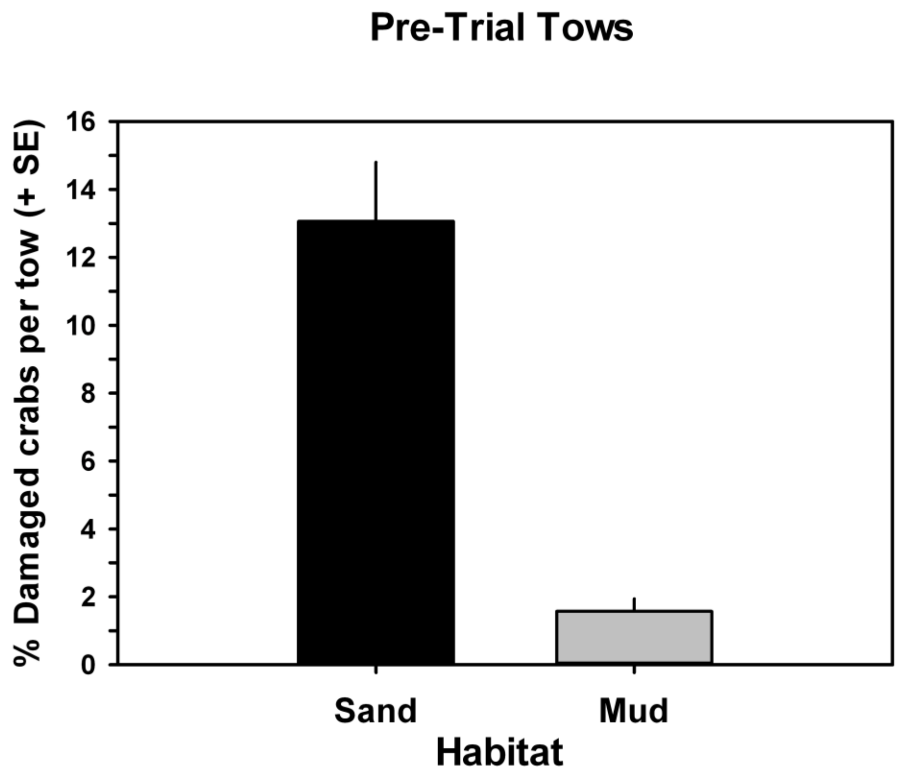


Figure 8: In pre-trial standardized tows, the percent of damaged crabs caught per tow was significantly higher ($p < 0.05$) in sand than in mud. Note that divers were used in all standardized tows.

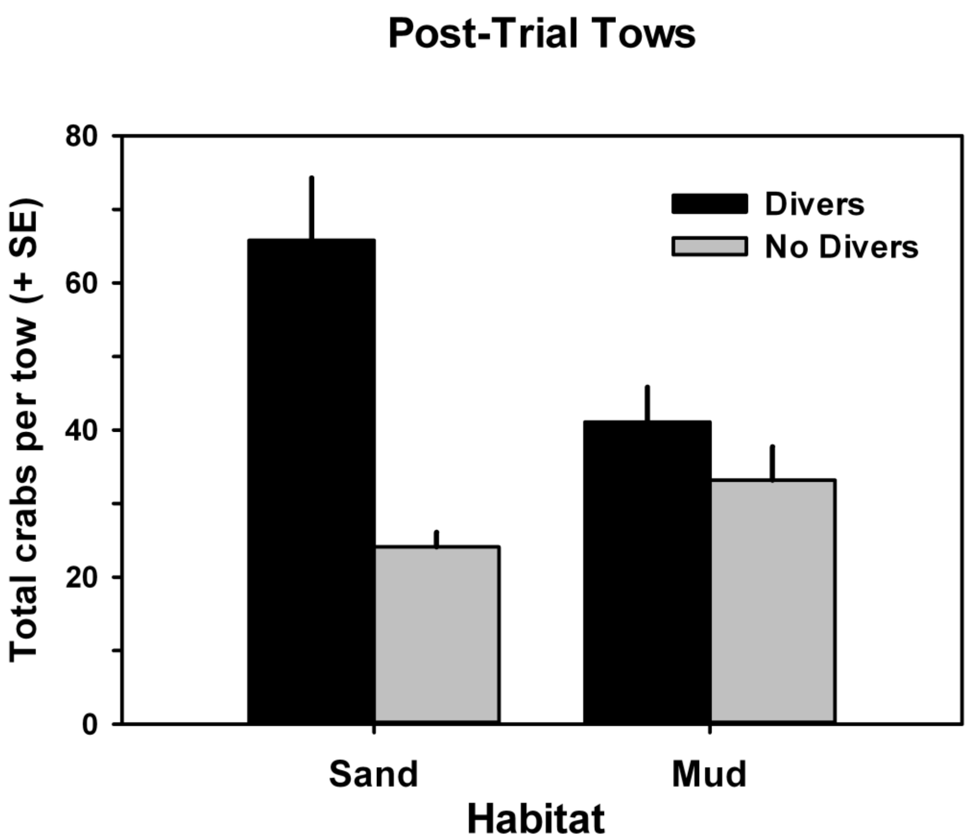


Figure 9: In post-trial standardized tows, the total number of crabs caught per tow was significantly higher ($p < 0.05$) in sand than in mud, and with divers than without divers. However, the difference between catches in mud with and without divers did not differ substantially. Note that divers were used in all standardized tows.

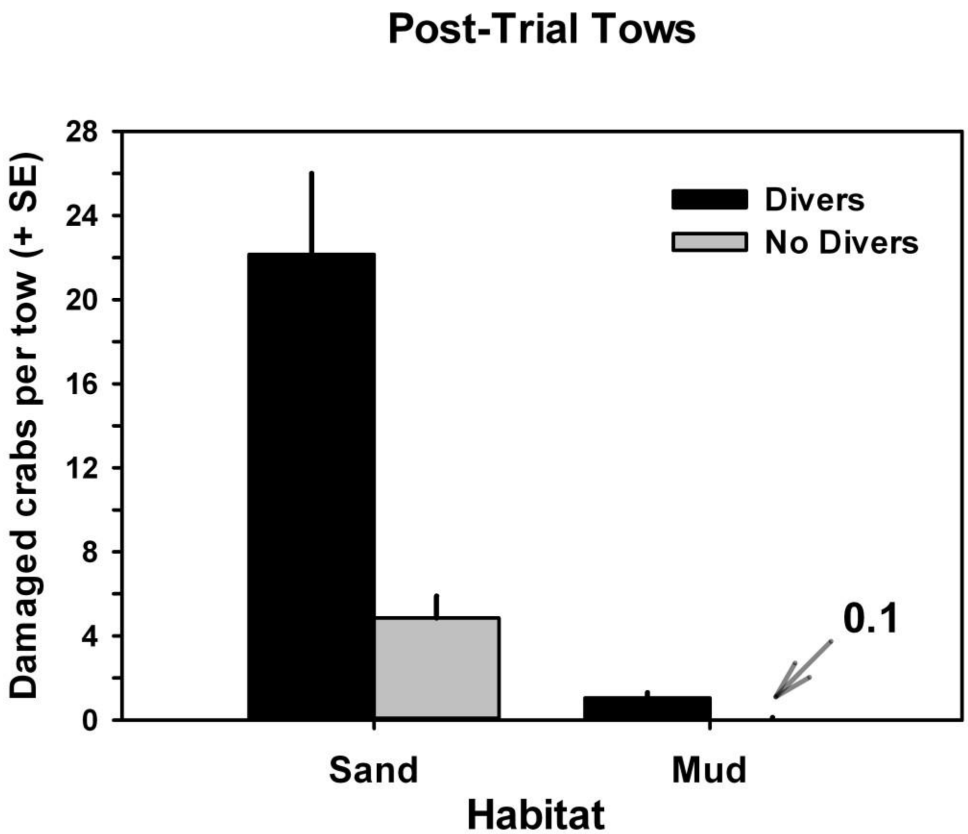


Figure 10: In post-trial standardized tows, the number of damaged crabs caught per tow was significantly higher ($p < 0.05$) in sand than in mud, and with divers than without divers, although there were very few damaged crabs caught in mud. Note that divers were used in all standardized tows.

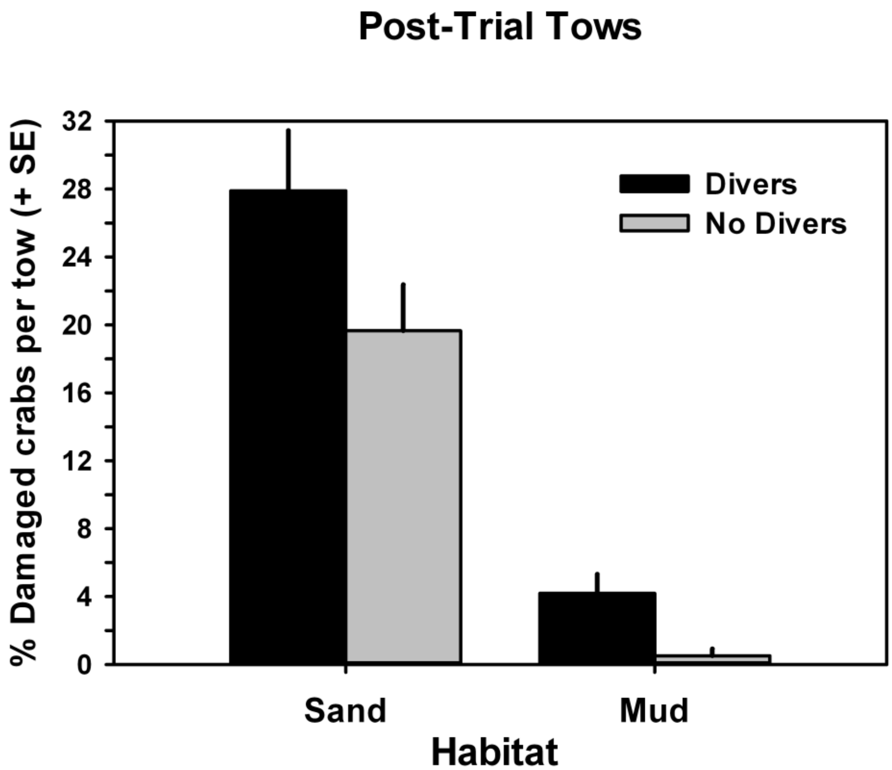
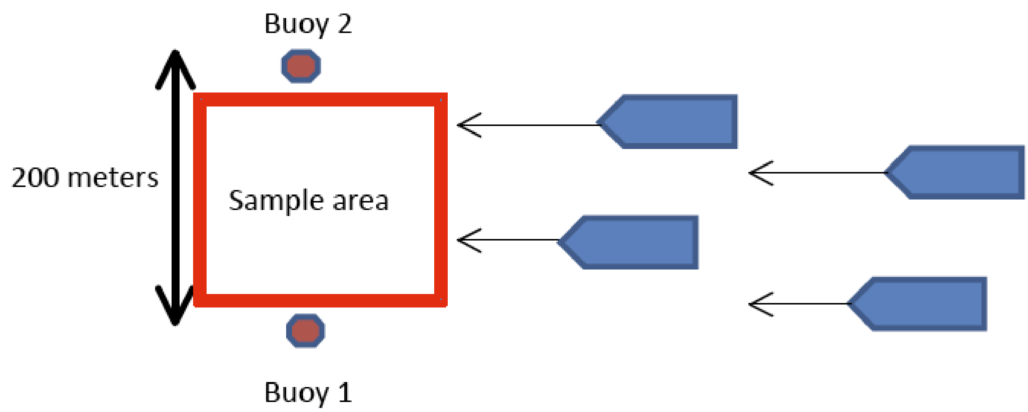


Figure 11: In post-trial standardized tows, the percentage of damaged crabs caught per tow was significantly higher ($p < 0.05$) in sand than in mud, and with divers than without divers, although there were very few damaged crabs caught in mud. Note that divers were used in all standardized tows.

5. Appendix Figure



Appendix Figure 1: Layout of the sampling area, buoys, and vessel (blue) paths.