Maryland's Conservation Equivalency Effectiveness Report
January 2019

Introduction

At the February 2018 Atlantic Striped Bass Management Board meeting, Maryland presented a conservation equivalency plan to lower the minimum size during the Chesapeake Bay summer/fall season with the primary goal of reducing dead discards. The proposal would increase harvest, but decrease dead discards and therefore have an estimated zero or minimal impact on total removals. Anglers were reporting a high number of discards in recent years as a result of the increase in minimum size from 18 to 20 inches during the 2015-2017 fishing seasons, and the availability of several strong year classes. The plan (Option B in proposal) reduced the minimum size from 20 to 19 inches and required the use of non-offset circle hooks when fishing with bait during the summer/fall fishery.

The motion read as follows:
"*Move to approve Option B, in Maryland's conservation equivalency proposal for its summer/fall recreational striped bass fishery in the Chesapeake Bay. Season, May 16 to December 15. Size and bag, 2 fish at 19 inch minimum, with only 1 fish allowed greater than 28 inches. Non-offset circle hooks required when fishing with bait, non-artificial lures. Additionally, Maryland will collect enforcement, compliance and other relevant information during 2018, and will report back to the Board with a conservation equivalency effectiveness review in February, 2019.*" The motion passed, with 15 in favor and 1 abstention.

Maryland was able to pass emergency regulations in time for the entire 2018 summer/fall fishery, May 16 – December 15. During the public scoping process following the board meeting, it was determined that requiring circle hooks for all bait fishing would negatively impact tackle shops and anglers targeting species other than striped bass. As the majority of striped bass are targeted using chumming and live-living, the final regulation required the use of non-offset circle hooks while chumming and live-lining, but J-hooks or circle hooks could be used when fishing with dead bait. The regulations were written with a two year sunset provision and they will expire on Dec. 15, 2019. Maryland intends to maintain these recreational measures for the 2019 summer/fall fishery.

Maryland took several steps to educate anglers and assess compliance with the new regulations. This conservation equivalency effectiveness report serves to present that information as required by the board.

Outreach and Education

The Maryland Department of Natural Resources (DNR) developed a multifaceted approach to support implementation of the conservation measure. This involved educating the fishing public on the new requirements and the benefits of circle hooks through all platforms at the unit's disposal including:

- Distribution of printed outreach material via department service centers, parks, outdoor retail outlets, recreational fishing survey crews and stakeholder events like the Maryland State Fair: 21,000 business cards, 700 index cards, 100 posters and 500 stickers.
- Five separate emails, distributed to approximately 100,000 email addresses.
- Eight seminars devoted to the topic and seven industry shows covering 30 days.
- 15 postings on Facebook and Twitter before and during the fishing season, soliciting over 174,000 views by the public.
- Two 2-hour radio interviews on the Outdoorsman Radio Show.
- Website developed and launched, dedicated to the regulation and proper use of circle hooks.
- Two full press releases distributed to all state news outlets, one to announce the regulation and the second to encourage proper use of circle hooks and handling of fish.
- Multiple 5-minute weekly fishing reports on a local radio show to highlight the new regulation and use of circle hooks.

During 2019, the department plans to continue educating the public on the regulation and the benefits of circle hooks, utilizing many of the same outlets listed above. Staff plan to engage the public at fishing shows and give presentations to additional fishing clubs. To date, staff are scheduled to present at two fishing clubs and work at a booth during two winter outdoors shows (covering 12 days). Another initiative planned for 2019 is the distribution of 2,000 non-offset circle hooks while engaging the public on the topic.

Enforcement and Compliance

Natural Resources Police
Saturation patrols were conducted over the summer by the police. In total, 40 boats (charter and recreational) were boarded and gear was checked for compliance with the circle hook regulation. One warning was issued to a charter boat using J-hooks indicating nearly 100 percent compliance.

Access Point Angler Intercept Survey (APAIS)
The survey is part of the National Oceanic & Atmospheric Administration's (NOAA) Marine Recreational Information Program (MRIP) and has been conducted for over 26 years. MRIP staff are responsible for survey design, recreational catch and effort estimation, and public data dissemination. As part of MRIP, DNR APAIS staff conduct interviews and collect data using protocols designed by NOAA Fisheries. The survey takes place at beaches, piers, marinas, docks and other marine access sites throughout Maryland and collects data on the catch, participation and effort of recreational anglers. The table below summarizes the number of intercepts for 2018.

Wave	Number of Charter Angler Interviews	Number of Private Angler Interviews	Number of Shore Angler Interviews	Number of All Interviews Obtained
3 (May/Jun)	360	1,012	281	1,653
4 (Jul/Aug)	285	556	352	1,193
5 (Sept/Oct)	137	445	136	718
6 (Nov/Dec)	37	198	123	358
2018 TOTAL	**900**	**2,485**	**1,009**	**4,394**

During summer/fall 2018, DNR staff included two additional circle hook questions, separate from the APAIS questionnaire, in order to assess compliance with the new circle hook regulations. When interviewers had time available with zero impact to the regular conduct of APAIS, staff asked these two additional questions of

saltwater, recreational, finfish anglers who had completed their fishing for the day and were fishing using hook and line from either shore or private/rental boats in Chesapeake Bay waters. Charter anglers were not asked these questions. The two questions were:

- Q1: Were you primarily chumming or live lining or fishing with bait today? (IF no/don't know/refused then end survey)
- Q2: Were you using circle hooks while using [fishing method from Q1] today?

After interviews, staff distributed circle hook information cards and notes on handling fish during the summer heat. We plan to continue the circle hook questionnaire during 2019 sampling and will distribute circle hooks and other outreach material as a thank you for participating.

Analyses

Summary of APAIS Circle Hook Questionnaire

Between May 16 and Dec. 16, 2018, APAIS staff asked 887 anglers to participate in the circle hook interviews. Of these interviews, 1 angler refused the interview, 10 anglers didn't know what fishing method they were using, and 4 interviews did not have fishing method entered. The majority of the interviews (61 percent) were conducted in June, July and November.

As the circle hook gear regulations were not striped bass specific, these interviews included anyone fishing using hook and line from shore or private/rental boats in Chesapeake Bay. Of the 872 interviews completed with known fishing method, 400 anglers (45.9 percent) were not chumming, live lining, or using bait and were therefore exempt from the new circle regulations. These anglers were likely trolling or using artificial lures. Of the anglers that were subject to the new circle hook regulations:

- 48 (5.5 percent) anglers reported that they were chumming and 45 of the 48 (94 percent) reported using circle hooks.
- 34 (3.9 percent) anglers reported that they were live lining and 33 of the 34 (97 percent) reported using circle hooks.
- 390 (44.7 percent) anglers reported that they were fishing with baited hooks. Of these 390 anglers, 119 (30.5 percent) reported using circle hooks. As the use of treble hooks was banned when using bait, the remaining anglers were likely using J-hooks.

Overall, compliance with the use of circle hooks when chumming and live lining among shore or private/rental boat anglers was high (>90 percent), suggesting that outreach efforts on the new regulations were successful in making anglers aware of the new requirements. Live lining was a smaller proportion of the Chesapeake Bay summer/fall fishery than expected, which may be due to the following: 1) the additional APAIS questions were asked of all hook and line anglers, not just those targeting striped bass; 2) live lining may be more popular with the charter boat fleet than the private fleet; 3) the scarcity of small spot in recent years may have lowered the prevalence of live lining; and 4) a lower number of circle hook interviews were conducted in August and September when live lining is popular, likely due to APAIS interviewers not having time to ask the additional circle hook questions of anglers.

Quantitative Analyses of Regulatory Changes

The minimum size limit for striped bass was 20 inches for the 2015-2017 fishing seasons and was decreased to 19 inches for 2018. It was expected that reducing the minimum size limit would result in fewer discards while increasing harvest. The reduction in discards was expected to come not only from discarded fish being harvested, but from anglers limiting out more quickly and not discarding as many fish.

First, the 2018 MRIP harvest and discard estimates were examined. The 2018 wave 6 estimates of harvest and live releases from MRIP have not yet been released, so the comparisons of the harvest and live releases will focus on preliminary data from waves 3-5 (May-October). The results of this comparison suggest that some, but not all, waves in 2018 had higher harvest and lower discards compared to 2015-2017 (Figure 1). Analysis of this nature is complicated by the fact that other factors can affect harvest and discards year to year, regardless of regulatory changes. These factors include year class strength, such as the large 2011 and 2015 year classes moving into and through the fishery, as well as weather, fish distribution patterns, and changes in angler behavior. In addition to this straightforward comparison of 2018 with 2015-2017 estimates of harvest and discards, another attempt to quantify the success of the regulation was made and is explained below.

Updated Analysis of Original Proposal

The original conservation equivalency proposal submitted by Maryland in December 2017 used data from 2000-2014 to estimate the expected total removals when reducing from a 20 inch minimum size limit to a 19 inch minimum size limit. These years were used in the analysis as regulations were constant and they reflected a variety of fishing conditions (strong and poor year classes, various weather conditions, etc). While specific years were estimated to have a net increase or decrease in total removals when going from a 20 inch minimum size to a 19 inch minimum size, the average percent change in total removals over those years was zero. This means that on average, we would expect a 0 percent change in total removals when going from a 20 to 19 inch minimum size limit. Several assumptions were made regarding fishing methods and circle hook use in the original analysis. Specifically, the proportions of anglers using artificial lures (i.e. trolling) and bait (i.e. chumming and live lining) were estimated by month based on general knowledge of the striped bass fishery. Additionally, it was assumed that all anglers using bait (i.e. chumming, live lining, or using other cut bait) would be using circle hooks, an assumption that did not ultimately align with the final regulations. Through the circle hooks questions asked by APAIS interviewers, we were able to quantify these two assumptions and adjust our calculations to reflect the observed 2018 values of fishing method and circle hook usage. In addition, we updated the analysis to use the new estimates of harvest and live releases following the MRIP update in 2018.

The estimates of fishing method (bait vs. artificials) were fairly similar between the original and updated analyses, differing by less than 15 percent in all waves (Table 1). However, the observed proportion of bait fishermen (e.g. chumming, live lining, or using cut bait) using circle hooks ranged from 26-63 percent depending on wave and was lower than the 100 percent circle hook usage assumed in the original analysis (Table 1). While almost all anglers chumming or live lining used circle hooks as required by the regulation, a lower proportion of anglers fishing with cut bait used circle hooks. This is unsurprising as anglers fishing with cut bait were allowed to use either circle hooks or J-hooks. Based on the wave 3-5 private and shore MRIP interviews in 2018, and assuming that these circle hook interviews are representative of the overall private and shore based MRIP sample, approximately 50 percent of the anglers fishing in Chesapeake Bay said they were targeting striped bass.

Similar to the original conservation equivalency proposal, analyses were conducted two ways: 1) assuming a 9 percent discard mortality rate across all waves and 2) a 27 percent discard mortality rate in waves 3-4 and a 9 percent discard mortality rate in waves 5-6 (Table 2). This higher mortality rate was based on a study by Lukacovic and Uphoff (2007), which documented higher release mortality in June and July due to high water and air temperatures. In both scenarios, an adjusted (lower) discard mortality was also applied to account for the lower mortality associated with circle hook use, as described in the original proposal.

In the updated analysis under scenario 1 (9 percent discard mortality and decreasing from a 20 to 19 inch minimum size), the dead discards are expected to decrease 10-14 percent (average=12 percent), harvest is expected to increase 11-38 percent (average=21 percent), and total removals are expected to range from a 1

percent decrease to a 13 percent increase (average=6 percent increase). In the updated analysis under scenario 2 (27 percent mortality in waves 3-4 and decreasing from a 20 to 19 inch minimum size), the dead discards are expected to decrease between 10-13 percent (average=11 percent), harvest is expected to increase between 11-38 percent (average=21 percent), and total removals are expected to range from a decrease of 4 percent to an increase of 7 percent (average=1 percent increase). The results of this analysis align with Option B approved in the original conservation equivalency proposal. In the original proposal, we estimated that there would be a 0 percent change in total removals ± 2.5 percent; however, estimated changes in total removals ranged from -8 percent to +7 percent. While the final circle hook regulations did not result in as many dead discards being saved as originally anticipated, the 6 percent average calculated in the updated analysis is still within the range calculated in the original proposal.

Conclusion

Maryland was successful in implementing new regulations (19 inch minimum size, mandatory use of non-offset circle hooks while chumming or live-living) prior to the start of the 2018 summer/fall fishery through the use of emergency regulations. An extensive public outreach campaign educated anglers on the new regulations and benefits of circle hooks through a variety of sources including distribution of printed materials, emails, social media, presentations, radio shows and press releases. Data collected by the Maryland Natural Resources Police showed high compliance with the new regulations for both charter boat and recreational anglers. Additionally, APAIS staff on the ground helped get the word out and questioned almost 900 shore and private boat anglers about their compliance with the new regulation. The APAIS interviews showed >90 percent compliance with the use of circle hooks when chumming and live lining. Lastly, while the final circle hook regulations did not result in as many dead discards being saved as originally anticipated, the 6 percent average calculated in the updated analysis is still within the range calculated in the original conservation equivalency proposal.

Overall, Maryland feels the public was adequately informed and complied with the new regulations. Maryland will be using these same regulations in the 2019 fishing season. Outreach on circle hook usage and proper fish handling, particularly in summer when discard mortality is highest, will continue throughout 2019.

Table 1. Estimated proportion of anglers by fishing method used in the original analysis compared to the observed proportions of fishing method and circle hook usage by bait anglers from the APAIS circle hook interviews. Bait anglers in this analysis include any anglers chumming, live lining, or fishing with cut bait.

	Original Analysis		**Updated Analysis**		
Wave	**Artificials**	**Bait**	**Artificials**	**Bait**	**Proportion Bait Anglers Using Circle Hooks**
3	0.42	0.58	0.41	0.59	0.49
4	0.25	0.75	0.39	0.61	0.26
5	0.50	0.50	0.56	0.44	0.63
6	0.75	0.25	0.70	0.30	0.32

Table 2. Method 1 estimates of the proportion change in dead discards, harvest and total removals using the updated circle hook data. The top table assumes a 9 percent mortality rate for the entire fishing season. The bottom table assumes a 27 percent mortality rate in waves 3-4.

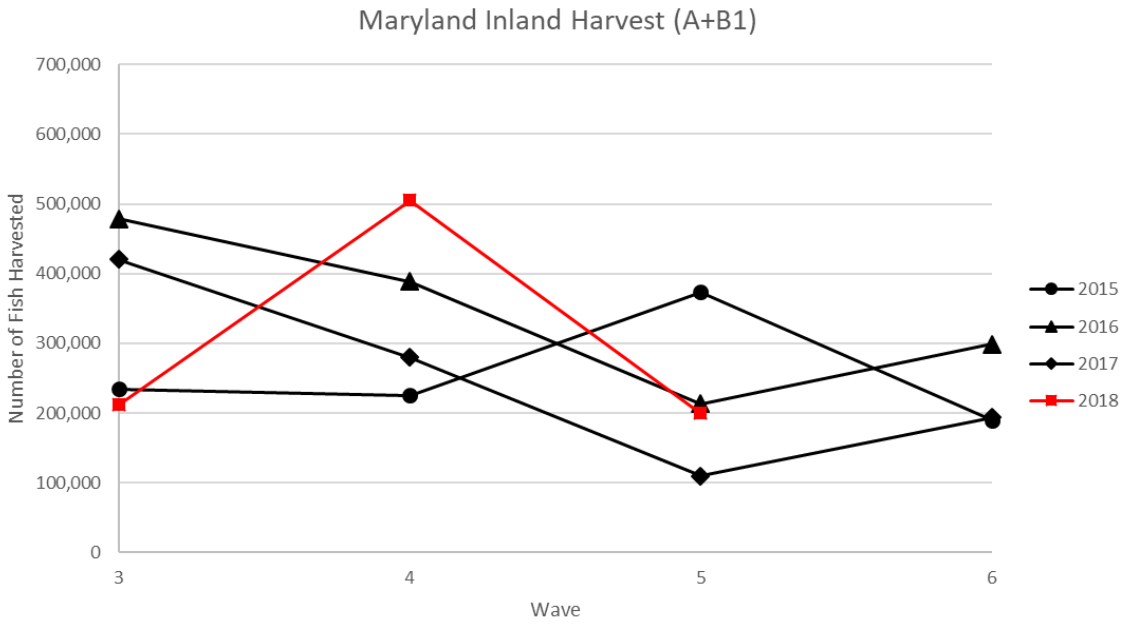
Assuming 9 percent Discard Mortality in All Waves

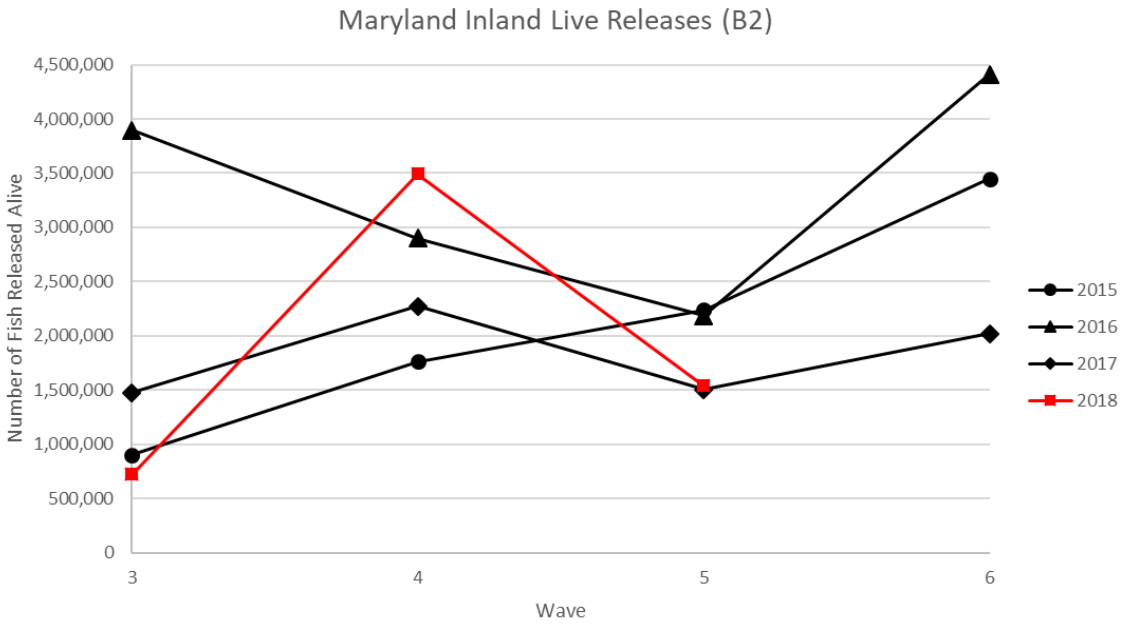
Year	Reduction 20”->19" Proportion Change Dead Discards	Reduction 20”->19" Proportion Change Harvest	Reduction 20”->19" Proportion Change Total Removals
2000	-0.12	0.38	0.13
2001	-0.11	0.22	0.05
2002	-0.11	0.17	0.01
2003	-0.11	0.20	0.02
2004	-0.11	0.20	-0.01
2005	-0.10	0.25	0.03
2006	-0.11	0.24	0.07
2007	-0.13	0.27	0.10
2008	-0.11	0.13	0.05
2009	-0.12	0.11	0.05
2010	-0.13	0.22	0.10
2011	-0.14	0.14	0.07
2012	-0.11	0.19	0.01
2013	-0.12	0.23	0.08
2014	-0.11	0.23	0.09
Average	**-0.12**	**0.21**	**0.06**

Assuming 27 percent Discard Mortality Waves 3 & 4 and 9 percent Discard Mortality in Waves 5-6

Year	Reduction 20”->19" Proportion Change Dead Discards	Reduction 20”->19" Proportion Change Harvest	Reduction 20”->19" Proportion Change Total Removals
2000	-0.12	0.38	0.07
2001	-0.11	0.22	0.02
2002	-0.10	0.17	-0.02
2003	-0.11	0.20	-0.02
2004	-0.10	0.20	-0.04
2005	-0.10	0.25	-0.02
2006	-0.12	0.24	0.02
2007	-0.13	0.27	0.05
2008	-0.11	0.13	0.01
2009	-0.12	0.11	0.01
2010	-0.12	0.22	0.04
2011	-0.13	0.14	0.04
2012	-0.10	0.19	-0.03
2013	-0.11	0.23	0.01
2014	-0.11	0.23	0.03
Average	**-0.11**	**0.21**	**0.01**

Figure 1. Estimates of harvest and live released from the MRIP program. 2018 estimates are preliminary and incomplete. Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, Dec. 18, 2018.





November 19, 2018

Ms. Kelly Denit
Division Chief
Office of Sustainable Fisheries, National Marine Fisheries Service
1315 East-West Highway, SSMC3
Silver Spring, MD 20910

Dear Ms. Denit:

The American Sportfishing Association (ASA), the trade association representing the recreational fishing industry, does not support removing the current prohibition on recreational Atlantic striped bass fishing in the Block Island Transit Zone (BITZ) and asks that the National Marine Fisheries Service not move forward with rulemaking.

While we understand the motivations behind this proposal are focused simply on allowing recreational harvest in this geographical anomaly so as to reduce regulatory confusion and spread out fishing effort, we are concerned about potential unintended consequences. If allowed in this instance, it is likely that proposals to reopen other parts of the Exclusive Economic Zone (EEZ) to striped bass harvest, including for commercial harvest (citing "non-discrimination" under National Standard 4 of the Magnuson-Stevens Act), will emerge. The cumulative impacts of expanding striped bass harvest into areas of the EEZ may threaten the sustainability of the stock.

Many anglers and fisheries managers are concerned with trends in the condition of the striped bass population. Given that a new benchmark stock assessment will not be ready until 2019, and that no analysis has been conducted to determine the potential impacts of opening the BITZ to harvest, moving forward with this proposal could risk the future health of the striped bass stock.

The prohibition on striped bass harvest in the EEZ has unquestionably been an extremely valuable conservation measure. The "slippery slope" that could be created by allowing harvest in the BITZ is too great of a risk. We therefore request that the National Marine Fisheries Service safeguard the EEZ closure and maintain the existing prohibition on striped bass harvest in the BITZ.

Sincerely,

Mike Leonard
Vice President, Government Affairs

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A Synthesis of Scientific Findings on Menhaden's Role in the Chesapeake Bay Ecosystem and Their Relevance to the Chesapeake Bay Reduction Fishery Cap

Prepared by Dr. Katie Drew

Introduction

The Atlantic States Marine Fisheries Commission (ASMFC) requested a synthesis of existing scientific evidence on the importance of Atlantic menhaden in the Chesapeake ecosystem to help inform management decisions about harvest levels in the Chesapeake Bay. This review was conducted by ASMFC staff and is not a product of ASMFC's Menhaden Technical Committee (TC) or Ecological Reference Point Working Group (ERP WG).

This synthesis reviews the literature that informed the 2015 Atlantic menhaden benchmark stock assessment (SEDAR 2015) and Amendment 3 (ASMFC 2017) to the Atlantic Menhaden Fishery Management Plan (FMP). It does not reflect the most recent and ongoing work of the Stock Assessment Subcommittee (SAS) or the ERP WG, which will be completed as part of the 2019 single-species and ecological-based benchmark assessments.

History of the Chesapeake Bay Cap

In the years leading up to Amendment I (2001) to the Atlantic Menhaden FMP, the number of reduction plants and vessels in the reduction fleet had declined along the coast, with effort concentrating in Virginia and North Carolina. As a result, total landings along the coast and from Chesapeake Bay (Bay) also declined, but the proportion of removals from the Bay increased (ASMFC 2005a). The higher proportion of effort in the Chesapeake Bay and the lower levels of recruitment to the Bay raised concerns about the possibility of localized depletion, defined as a reduction in menhaden population size/density below the level of abundance that is sufficient to maintain its basic ecological (e.g. forage base, grazer of plankton), economic, and social/cultural functions, as a result of fishing pressure, environmental conditions, and predation pressures that occur on a small spatial or temporal scale.

In response to these concerns, ASMFC implemented a harvest cap on the reduction fishery in Chesapeake Bay through Addendum II (ASMFC 2005), limiting removals of Atlantic menhaden from the Bay for reduction purposes to the average of 2000-2004 landings to be implemented in the 2006 fishing year. Before its first year of use, the cap was revised through Addendum III (ASMFC 2006) to be the average landings from 2001-2005, or 109,020 mt. The cap was reduced by 20% in 2013 to 87,216 mt with the concurrent implementation of a coastwide quota which also represented a 20% reduction from recent average landings (ASMFC 2012). Amendment 3 further reduced the Bay cap to 51,000 metric tons, approximately equal to the five-year average of reduction harvest from the Chesapeake Bay between 2012 and 2016 (ASMFC 2017). Reduction landings from Chesapeake Bay have not exceeded 51,000 mt since 2012, even under the higher historical caps.

In response to the concerns raised in Addendum II, the NOAA Chesapeake Bay Office coordinated funding for a series of research projects to address the question of whether localized depletion was occurring in Chesapeake Bay. These projects were reviewed in 2009 by a panel appointed by the Center for Independent Experts. The panel determined that the individual research projects were relevant and well-designed, and the results of many of them informed this synthesis. However, the panel noted that without an operational definition of depletion, it could not be determined whether localized depletion was occurring or how well the ongoing research could address that question (Maguire 2009).

Atlantic Menhaden Life History

Genetic studies indicate Atlantic menhaden are a single stock on the Atlantic coast (Anderson 2007; Lynch et al. 2010). Juvenile and adult menhaden make seasonal migrations along the Atlantic coast, moving inshore and north in the spring and offshore and south in fall (Nicholson 1978). Larger, older individuals migrate further north. This results in different size and age classes being available to the fishery in different regions; fisheries operating in the Chesapeake Bay and further south harvest a higher proportion of age-1 and age-2 fish compared to fisheries operating further north (SEDAR 2015).

Adults spawn on the continental shelf throughout the year as they migrate, with the peak of spawning generally occurring from December through March (Nicholson 1978; Lewis et al. 1987). Larvae are then carried into bays and estuaries where they settle as age-0 recruits. The Chesapeake Bay is one of the important nursery grounds for Atlantic menhaden. Otolith microchemistry analysis showed that from 2010 – 2012, individuals from Chesapeake Bay made up about 30% of the exploitable Atlantic menhaden (ages 2-4) on the coast (Anstead et al. 2017).

The abundance of age-0 menhaden within Chesapeake Bay in any given year is influenced by a combination of offshore and inshore factors. This includes things such as large scale climatic regimes like the Atlantic Multidecadal Oscillation (Bucheister et al. 2016) and annual variability in the abundance of phytoplankton and zooplankton within the Bay (Houde et al. 2016). Total spawning stock biomass (SSB) along the coast may also play a role, although the relationship between coastwide SSB and recruitment stock-wide is weak (SEDAR 2015). The TC was unable to detect a relationship between abundance of age-2 and age-3 menhaden in the Bay and recruitment to the Bay the following year (ASMFC 2005b).

Atlantic Menhaden's Role in the Ecosystem

As larvae, Atlantic menhaden feed on zooplankton, but as juveniles and adults, they consume primarily phytoplankton by filtering seawater through specialized gill rakers (June and Carlson 1971, Friedland 1985, Friedland et al. 2006). Modeling work suggests that Atlantic menhaden may have a dampening effect on large algal blooms in Chesapeake Bay through their feeding (Dalyander and Cerco 2010), but are likely not reducing the total nitrogen load in the Bay (Lynch et al. 2010, Friedland et al 2011).

Atlantic menhaden are also an important forage species. Numerous studies have been conducted on the food habits of fish species within the Chesapeake Bay; however, it is difficult to compare the results directly because studies often occurred in different seasons, sampled different size ranges of predators, and use different methods of calculating the species composition in a diet. In addition, the proportion of Atlantic menhaden in species' diets can change across years, depending on the relative abundance of Atlantic menhaden and other prey species. For example, Overton (2015) found that striped bass in the Chesapeake Bay had a higher proportion of Atlantic menhaden in their diet in the 1950s, when menhaden abundance along the coast and recruitment of menhaden to Chesapeake Bay were high, than during the mid-1990s to early 2000s when menhaden abundance along the coast and recruitment of menhaden to Chesapeake Bay were both low.

During the 2010 and 2015 benchmark stock assessment for Atlantic menhaden, the ASMFC Multispecies Technical Committee did a thorough review of published studies and food habits databases from fishery independent sources such as the NEFSC Food Habits Database, NEAMAP, ChesMMAP, and CHESFIMS in order to parameterize the MSVPA-X model (SEDAR 2015). They synthesized average diet composition information by season and size class for several important predator species (Table 1). The prevalence of menhaden in predators' diets varied across seasons and size or age classes. For example, the percent by weight of Atlantic menhaden in striped bass stomach contents ranged from over 90% for age 8+ striped bass in the winter to less than 10% of age 1-2 striped bass in the spring. Similarly, the percent by weight of Atlantic menhaden in bluefish stomachs ranged from 3.5% to 50.4%, depending on the season and size class of bluefish.

Atlantic menhaden are also consumed by other predators such as piscivorous birds. The prevalence of Atlantic menhaden in bald eagles' diets in the Bay also showed seasonal patterns. Mersmann (1989) found that bald eagles consumed fish almost exclusively during the summer, the majority of which were gizzard shad and Atlantic menhaden; during the winter, bald eagles' diets were predominantly comprised of carrion from birds and mammals. McLean and Byrd (1991a) found that Atlantic menhaden made up 75% of the diet by number of nesting ospreys in the Chesapeake Bay in 1985. Glass and Watts (2009) found that the proportion of Atlantic menhaden in osprey diets depended on the location of the osprey nests: ospreys nesting in higher salinity regions of the Bay consumed a higher proportion of Atlantic menhaden (24% by number) than ospreys nesting in lower salinity regions (1.5% by number). However, overall, the diets of non-fish predators within the Chesapeake Bay are not well studied. For example, cormorant and heron abundance within the Bay has increased over time and both species are known to consume tidal freshwater fish like menhaden from studies in other regions, but there are no studies of their diet in Chesapeake Bay (Viverette 2007).

The body of diet work shows that Atlantic menhaden can make up a significant proportion of many predators diets' for specific seasons, size/age classes, and locations within the Bay, and that the prevalence of Atlantic menhaden in predators' diets changes with changing menhaden abundance. However, understanding the impact of reduced menhaden abundance on predator population health is much more difficult, and the evidence is less clear.

Some work has been done to estimate the predatory demand of individual species within the Bay (e.g., Hartman and Brandt 1995, Uphoff 2003), but whether there is enough menhaden biomass in the Bay to support this demand cannot be determined from the current coastwide stock assessment.

Lower levels of Atlantic menhaden abundance along the coast and lower levels of menhaden recruitment in Chesapeake Bay have been correlated with negative population metrics for some species. For example, striped bass reached coastwide highs in abundance during the late 1990s to early 2000s during a period of low menhaden abundance. However, within the Chesapeake Bay, the prevalence of mycobacteriosis in striped bass increased sharply (Uphoff 2003, Overton et al. 2003) while migratory striped bass outside the Bay had lower levels of infection (Matsche et al. 2010). Jacobs et al (2009) found that poor diet worsened the progression and severity of mycobacteriosis in striped bass in the lab. The weakfish population has continued to decline, even with greatly reduced fishing pressure, and an increase in natural mortality has been implicated (ASMFC 2014). As the population declined, recruitment indices remained relatively stable for weakfish, and the mortality bottleneck appears to be at around age 1-2, when weakfish switch over to consuming fish; one hypothesis is that the increase in natural mortality is linked to reduced prey availability including menhaden (NEFSC 2009). Osprey population growth rates in Chesapeake Bay were higher during the late 1970s and early 1980s, a period of high menhaden abundance and high recruitment to the Bay, than they were during the late 1980s and in 2006 (Watts 2007); McLean and Byrd (1991b) observed behavioral signs of food limitations such as sibling aggression in osprey in Chesapeake Bay in 1985 and noted that a similar study in 1975-1976 had not observed any sibling aggression.

However, all of these correlations come with many caveats. The increased prevalence of mycobacteriosis in striped bass in Chesapeake Bay has also been linked to environmental factors such as increased eutrophication and warming water temperatures in the Bay (Gauthier and Rhodes 2009). Cycles in weakfish landings are correlated with the Atlantic Multidecadal Oscillation, and age-0 weakfish are a major component of shrimp trawl bycatch (ASMFC 2014). Osprey showed higher population growth rates in low salinity areas where menhaden made up a lower proportion of their diet (Glass and Watts 2009). All of these populations are driven by many factors, including environmental conditions, habitat availability, overall forage abundance, and anthropogenic impacts, and parsing out the importance of menhaden abundance alone is difficult.

Conclusions

- There is currently no estimate of Atlantic menhaden abundance specifically within Chesapeake Bay and there is no quantitative determination of an appropriate depletion threshold, therefore there is no quantitative determination of whether localized depletion is or is not occurring.
- Recruitment to Chesapeake Bay does not appear to be correlated with abundance of age-2 and age-3 Atlantic menhaden within the Bay; as long as environmental conditions and total coastwide fecundity are favorable, recruitment to the Bay can occur.

- From a single-species perspective, the projections used to set the coastwide quota were conducted with the assumption that selectivity in the future would be equal to the selectivity of the most recent year of the model. The Bay fishery harvests a higher proportion of age-1 and age-2 fish than the more northern fisheries. Therefore, if the proportion of removals from the Bay changes, the impact of those removals on the total population will change even if the coastwide quota is not exceeded, because the overall selectivity pattern will be different.
- Demand for forage in Chesapeake Bay from fish and bird predators has increased since the early to mid-1980s, the last period of strong recruitment to Chesapeake Bay (Uphoff 2003, Viverette 2007).
- Atlantic menhaden can make up a significant proportion of many predators diets' for specific seasons, age classes, and locations within the Bay, particularly when menhaden are abundant.
- Lower levels of Atlantic menhaden abundance and recruitment have been linked to negative population metrics for several species within the Bay, but the overall complexity of the Chesapeake Bay food web, changing environment, and population dynamics makes it difficult to prove causation.

References

Anderson, J.D. 2007. Systematics of the North American menhadens: molecular evolutionary reconstructions in the genus *Brevoortia* (Clupeiformes: Clupeidae). Fishery Bulletin 205:368-378.

Anstead, K.A., J.J. Schaffler, and C.M. Jones. 2017. Contribution of Nursery Areas to the Adult Population of Atlantic Menhaden. Transactions of the American Fisheries Society 146: 36–46.

Atlantic States Marine Fisheries Commission (ASMFC). 2005a. Addendum II to Amendment 1 to the Interstate Fishery Management Plan for Atlantic Menhaden.

Atlantic States Marine Fisheries Commission (ASMFC). 2005b. Atlantic Menhaden Technical Committee Meeting Summary. February 8, 2005. Arlington, VA. 2p.

ASMFC. 2011. Atlantic Menhaden Stock Assessment and Review Panel Reports. Stock Assessment Report No. 10-02 of the Atlantic States Marine Fisheries Commission. Arlington, VA. 326 pp.

ASMFC. 2012. Amendment 2 to the Interstate Fishery Management Plan for Atlantic Menhaden.

ASMFC. 2013. Amendment 3 to the Interstate Fishery Management Plan for Atlantic Menhaden.

ASMFC. 2016. Weakfish Benchmark Stock Assessment and Peer Review Report. Arlington, VA. 270 pp.

Buchheister, A., Miller, T. J., Houde, E. D., Secor, D. H., and Latour, R. J. Spatial and temporal dynamics of Atlantic menhaden (*Brevoortia tyrannus*) recruitment in the Northwest Atlantic Ocean. ICES Journal of Marine Science 73: 1147–1159.

Dalyander, P.S. and C.F. Cerco. 2010. Integration of a fish bioenergetics model into a spatially explicit water quality model: Application to menhaden in Chesapeake Bay. Ecological Modelling 221: 1922–1933.

Friedland, K.D. 1985. Functional Morphology of the Branchial Basket Structures Associated with Feeding in the Atlantic Menhaden, Brevoortia tyrannus (Pisces: Clupeidae). Copeia 1985: 1018-1027.

Friedland, K.D., D.W. Ahrenholz, J.W. Smith, M. Manning, and J. Ryan. 2006. Sieving functional morphology of the gill raker feeding apparatus of Atlantic menhaden. J Exp Zool A Comp Exp Biol. 305:974-85.

Friedland, K.D., P.D. Lynch, and C.J. Gobler. 2011. Time Series Mesoscale Response of Atlantic Menhaden *Brevoortia tyrannus* to Variation in Plankton Abundances. Journal of Coastal Research 27: 1148-1159.

Gauthier, D.T. and Rhodes, M.W. 2009. Mycobacteriosis in fishes: a review. The Veterinary Journal 180: 33-47.

Glass, K.A. and B.D. Watts. 2009. Osprey diet composition and quality in high- and low-salinity areas of lower Chesapeake Bay. Journal of Raptor Research 43: 27-36.

Hartman, K.J. and S.B. Brandt. 1995. Predatory demand and impact of striped bass, bluefish, and weakfish in the Chesapeake Bay: applications of bioenergetics models. Canadian Journal of Fisheries and Aquatic Sciences 52:1667-1687.

Houde, E. D., Annis, E. R., Harding, L. W. Jr, Mallonee, M. E., and Wilberg, M. J. Factors affecting the abundance of age-0 Atlantic menhaden (*Brevoortia tyrannus*) in Chesapeake Bay. ICES Journal of Marine Science, 73: 2238–2251.

June, F. C., and F. T. Carlson. 1971. Food of young Atlantic menhaden, *Brevoortia tyrannus*, in relation to metamorphosis. Fishery Bulletin 68: 493-512.

Lewis, R. M., D. W. Ahrenholz, and S. P. Epperly. 1987. Fecundity of Atlantic Menhaden, Brevoortia tyrannus. Estuaries 10:347–350.

Lynch, A. J., J. R. McDowell, J. E. Graves. 2010. A molecular genetic investigation of the population structure of Atlantic menhaden (*Brevoortia tyrannus*). Fishery Bulletin 108:87-97.

Lynch, P.D., M.J. Brush, E.D. Condon, and R.J. Latour. 2010. Net removal of nitrogen through ingestion of phytoplankton by Atlantic menhaden *Brevoortia tyrannus* in Chesapeake Bay. Marine Ecology Progress Series 401: 195–209.

Maguire, J.J. 2009. Report on the evaluation of the Chesapeake Bay Fisheries Science Program: Atlantic Menhaden Research Program. Laurel, MD. 32p.

Matsche, M.A., Overton, A., Jacobs, J., Rhodes, M.R. and Rosemary, K.M., 2010. Low prevalence of splenic mycobacteriosis in migratory striped bass *Morone saxatilis* from North Carolina and Chesapeake Bay, USA. Diseases of aquatic organisms, 90: 181-189.

McLean, P.K. and M.A. Byrd. 1991a. The diet of Chesapeake Bay ospreys and their impact on the local fishery. Journal of Raptor Research 25: 109-112.

McLean, P.K. and M.A. Byrd. 1991b. Feeding Ecology of Chesapeake Bay Ospreys and Growth and Behavior of Their Young. The Wilson Bulletin 103: 105-111.

Mersmann, T.J. 1989. Foraging Ecology of Bald Eagles on the Northern Chesapeake Bay with an Examination of Techniques Used in the Study of Bald Eagle Food Habits. Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Fisheries and Wildlife Sciences. 131 p.

Nicholson, W. R. 1978. Movements and population structure of Atlantic Menhaden indicated by tag returns. Estuaries 1:141–150.

Northeast Fisheries Science Center. 2009. 48th Northeast Regional Stock Assessment Workshop (48th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 09-15; 834 p.

Overton, A.S., F.J. Margraf, C. A. Weedon, L. H. Pieper, and E. B. May. 2003. The prevalence of mycobacterial infections in striped bass in Chesapeake Bay. Fisheries Management and Ecology 10: 301 – 308.

Overton, A.S., J.C. Griffin, F.J. Margraf, E.B. May and K.J. Hartman. 2015. Chronicling Long-Term Predator Responses to a Shifting Forage Base in Chesapeake Bay: An Energetics Approach. Transactions of the American Fisheries Society 144: 956-966.

SEDAR. 2015. SEDAR 40 – Atlantic Menhaden Stock Assessment Report. SEDAR, North Charleston SC. 643 p.

Uphoff, J. H. 2003. Predator–prey analysis of striped bass and Atlantic menhaden in upper Chesapeake Bay. Fisheries Management and Ecology 10: 313-322.

Viverette, C.B., G.C. Garman, S.P. McIninch, A.C. Markham, B.D. Watts, and S.A. Macko. 2007. Finfish-Waterbird Trophic Interactions in Tidal Freshwater Tributaries of the Chesapeake Bay. Waterbirds 30: 50-62.

Watts, B.D. and B.J. Paxton. 2007. Ospreys of the Chesapeake Bay: Population Recovery, Ecological Requirements, and Current Threats. Waterbirds 30: 39-49.

Table 1. Average percent of menhaden by weight in the stomachs of key predators within the Chesapeake Bay by season and age or size class. (-- indicates no samples available.) Data from published studies and fishery independent surveys synthesized by the ASMFC Multispecies TC (SEDAR 2015).

Striped Bass														
	Age													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13+
Jan-Mar	--	0.0	10.0	33.3	54.2	63.4	75.4	82.9	89.3	93.7	91.6	94.0	94.3	93.0
Apr - Jun	0.0	0.2	7.8	15.4	16.8	17.6	22.5	30.2	24.6	29.3	46.0	34.3	36.3	36.3
Jul - Sep	0.0	16.2	14.2	23.8	27.4	29.2	24.7	13.7	28.7	43.8	30.6	43.4	76.5	36.4
Oct - Dec	0.0	7.8	66.1	71.1	73.0	73.1	74.2	74.3	75.0	74.9	75.0	75.0	75.0	75.0

Weakfish							
	Age						
	0	1	2	3	4	5	6+
Jan-Mar	--	0.0	0.0	0.0	0.0	0.0	--
Apr - Jun	0.0	0.0	0.0	0.0	6.9	--	--
Jul - Sep	1.7	2.4	5.7	3.3	3.4	--	--
Oct - Dec	0.9	6.7	22.8	16.8	39.2	69.4	61.2

Bluefish			
	Size Class		
	<34 cm	34-55 cm	>55 cm
Jan-Mar	--	--	--
Apr - Jun	3.5	20.4	16.7
Jul - Sep	8.7	50.8	40.8
Oct - Dec	4.4	32.9	32.9

Spiny Dogfish			
	Size Class		
	<34 cm	34-55 cm	>55 cm
Jan-Mar	0.0	37.3	19.1
Apr - Jun	--	0.0	--
Jul - Sep	--	--	--
Oct - Dec	--	25.6	--