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# The Fate of an Atlantic Menhaden Year Class

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## ABSTRACT

The following analysis tracks a hypothetical year class, using the number of individuals at each age from the SEDAR Assessment Document, averaged over the ten year period 2004-2013 to account for inter-annual variability in year class size. The losses at each age due to fishing mortality, both reduction and bait, are similarly averaged for the same 10 year period for consistency in the analysis. What the analysis sets out to demonstrate and what the calculations convincingly show is that the losses from fishing mortality are very small in comparison to the number of fish in the population and equally minimal in comparison to the losses of billions of fish to natural mortality, as a year class ages from 0 to 6 years of age. The reduction fishery harvest, 0.807 billion fish, as a percentage of the starting year class size of 15.264 billion fish is 5.3%, and the bait fishery harvest, 0.165 billion fish, as a percentage is 1.1%.

**The reduction fishery harvested only 5.3% of a hypothetical year class derived from averaging numbers of fish at each age over the 2004-2013 time period. The bait fishery harvested another 1.1%. The total fishing mortality amounted to only 6.4% of the year class during the recent 10 year time period**.

## INTRODUCTION

The Atlantic menhaden, *Brevoortia tyrannus,* is an important forage fish species, ranging from Maine through to Florida, which serves as an important food item for many predator species and supports important commercial fisheries for reduction and bait. Typical of most forage fish species, the Atlantic menhaden forms dense schools of fish which are comprised of extraordinarily large numbers. Spawning occurs during the winter months in offshore areas generally ranging from New Jersey to North Carolina. The eggs and larvae produced from these mass spawning events are then dispersed by ocean and wind currents and are advected into the estuaries along the Atlantic coast for development and growth. The size of an Atlantic menhaden year class, also called a cohort of that year's spawning, is greatly influenced by environmental factors and only to a limited extent by the size of the spawning stock biomass or number of eggs produced. Once within the Atlantic coastal estuaries, the success of any year's spawning can be measured in the number of Age-0 fish (also called young-of-year) that survive and become recruits to the stock.

Most forage fish species experience high naturally occurring variations in spawning success due to the complexities of environmental factors affecting survival of fertilized eggs and larvae. In the most recent peer reviewed SEDAR 40 benchmark assessment, the Beaufort Assessment Model (BAM) estimates the size of each year class in billions of fish being recruited into the stock each year from 1955 through 2013. Each year class can be tracked from Age-0 through Age-6 to examine the survivability of a year class of fish and can be estimated at each age after landings to determine their impact on the stock over time. Natural mortality losses, such as those due to predation, naturally occurring fish kills, power plant impingement and entrainment, etc. can also be estimated by subtracting the fishing mortality losses from the number of fish that die each year as its numbers decrease from Age-0 to Age-6. Losses each year to natural mortality depend on age, being extremely high at Ages 0 and 1 in particular, and dropping to lower numbers for older menhaden.

It can be difficult for fisheries managers to keep due perspective on the numbers, the numbers of fish at age, usually presented in billions of individual fish, with the numbers of fish lost to natural and fishing mortality each year, in the context of the size of the stock. Fishing mortality losses from the reduction fishery are usually presented in metric tons, but also can be expressed in millions of pounds. The commercial bait fishery landings, on a smaller scale, are more commonly presented in millions or thousands of pounds. However, the largest source of mortality by far, the natural mortality, is rarely mentioned or depicted in direct comparison with fishing mortality losses.

The following analysis attempts to demonstrate the multiple losses at age for a hypothetical, though not atypical, year class as it grows from Age-0 through Age-6. The analysis depicts the magnitude of losses for the year class as it ages, keeping the losses of natural mortality and both types of fishing mortality, reduction and bait separately, so they can be seen in proper perspective.

## METHODS AND MATERIALS

Since the size of an Atlantic menhaden year class varies annually so much from year to year, the average number of individuals starting out each year as Age-0 fish for the 10 year period, 2004-2013, was calculated to represent the prototype of a year class, a hypothetical year class, to be followed throughout most of its life. The average number of individuals from the ten year period, 2004-2013, was selected to account for inter-annual variability in the strength of the age-0 year classes and represents the hypothetical year class. The time period, 2004-2013, also was selected because 2013 was the terminal year of data analysis for the most recent peer reviewed benchmark assessment.

The analysis uses data from the BAM Table 3. Numbers at age in billions of fish estimated from the base run of the BAM Model, 1955-2013. For example, for Age-0 fish, the size of a year class for this 10 year period ranges from 6.889 billion fish in 2013 to 26.954 billion fish in 2010, with the mean of 15.264 billion fish and a standard deviation of 6.370 billion fish. Similarly, the number of fish at Age-1 is averaged for the same 10 year period, with a mean of 5.216 billion fish and a standard deviation of 1.855 billion fish. Ages-2, 3, 4, 5, and 6 are all calculated in the same manner

**Table 3, Assessment Addendum Document, January 2015**
**Number at age in billions of fish estimated from the base run of the BAM Model, 2004-2013**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 2004 | 15.602 | 4.641 | 2.314 | 0.296 | 0.152 | 0.093 | 0.076 |
| 2005 | 24.053 | 5.053 | 1.913 | 0.757 | 0.127 | 0.078 | 0.100 |
| 2006 | 16.325 | 7.848 | 2.061 | 0.692 | 0.304 | 0.062 | 0.105 |
| 2007 | 13.483 | 5.327 | 3.298 | 0.815 | 0.269 | 0.141 | 0.097 |
| 2008 | 17.081 | 4.399 | 2.236 | 1.346 | 0.340 | 0.132 | 0.139 |
| 2009 | 13.482 | 5.573 | 1.866 | 0.952 | 0.588 | 0.171 | 0.160 |
| 2010 | 26.954 | 4.399 | 2.330 | 0.762 | 0.418 | 0.302 | 0.197 |
| 2011 | 10.151 | 8.795 | 1.807 | 0.877 | 0.298 | 0.199 | 0.291 |
| 2012 | 8.623 | 3.312 | 3.651 | 0.703 | 0.340 | 0.139 | 0.289 |
| 2013 | 6.889 | 2.814 | 1.393 | 1.507 | 0.287 | 0.163 | 0.256 |
| SUM | 152.643 | 52.161 | 22.869 | 8.707 | 3.123 | 1.480 | 1.710 |
| MEAN-10 years | 15.264 | 5.216 | 2.287 | 0.871 | 0.312 | 0.148 | 0.171 |

The fishing mortality losses at each age (in millions of fish), i.e. the catch at age, while not as variable from year to year as the size of the year class, are nonetheless averaged for the same 10 year period for consistency in this analysis and have been obtained from the BAM assessment document, Table 4.1.3.3.2 Estimated reduction landings of Atlantic menhaden in numbers at age (in millions), 1955-2013, and as a personal communication (bait landings), from the NOAA Beaufort Laboratory.

**Table 4.1.3.3.2 Estimated reduction landings of Atlantic menhaden in numbers at age (in millions), 2004-2013**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 |
|---|---|---|---|---|---|---|---|
| 2004 | 17.970 | 213.950 | 652.090 | 75.700 | 17.410 | 0.900 | 0 |
| 2005 | 12.100 | 78.860 | 382.890 | 154.190 | 18.680 | 1.820 | 0 |
| 2006 | 9.160 | 298.910 | 300.130 | 121.650 | 23.620 | 0.480 | 0 |
| 2007 | 1.140 | 239.200 | 609.240 | 69.430 | 12.970 | 0.680 | 0 |
| 2008 | 7.900 | 52.370 | 394.870 | 106.640 | 14.650 | 1.030 | 0 |
| 2009 | 4.390 | 352.410 | 228.950 | 130.820 | 19.920 | 1.840 | 0 |
| 2010 | 15.480 | 409.500 | 501.110 | 68.100 | 28.310 | 0.570 | 0 |
| 2011 | 0.000 | 418.470 | 493.060 | 65.140 | 8.860 | 1.720 | 0 |
| 2012 | 4.670 | 127.240 | 626.950 | 33.610 | 3.890 | 0.000 | 0 |
| 2013 | 22.130 | 240.010 | 284.840 | 76.260 | 10.110 | 0.250 | 0 |
| SUM | 94.940 | 2430.920 | 4474.130 | 901.540 | 158.420 | 9.290 | 0 |
| MEAN-10 years | 9.494 | 243.092 | 447.413 | 90.154 | 15.842 | 0.929 | 0 |

**Estimated bait landings of Atlantic menhaden in numbers at age (in millions), 2004-2013**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 2004 | 0 | 7.5 | 84.7 | 29.7 | 7.9 | 0.9 | 0.1 |
| 2005 | 0 | 1.7 | 55.2 | 51.7 | 6.9 | 0.8 | 0.1 |
| 2006 | 0 | 19 | 41.1 | 30.2 | 5.8 | 0.2 | 0 |
| 2007 | 0 | 34.5 | 112.1 | 34.7 | 8.1 | 0.5 | 0.1 |
| 2008 | 0 | 4.1 | 98.6 | 54 | 11.2 | 1.3 | 0 |
| 2009 | 0.3 | 23.4 | 46.2 | 59.9 | 13 | 0.9 | 0 |
| 2010 | 0 | 32.4 | 82.8 | 38.3 | 19.9 | 2 | 0.2 |
| 2011 | 0 | 39.2 | 63.8 | 66.1 | 36.9 | 4.9 | 0 |
| 2012 | 0 | 10.3 | 155.9 | 66 | 16.9 | 1.1 | 0.3 |
| 2013 | 0.9 | 60.3 | 46.6 | 48.6 | 11.2 | 1.8 | 0 |
| SUM | 1.2 | 232.4 | 787 | 479.2 | 137.8 | 14.4 | 0.8 |
| MEAN-10 years | 0.12 | 23.24 | 78.7 | 47.92 | 13.78 | 1.44 | 0.08 |

Thus, the number of fish alive at Ages 0, 1, 2, 3, 4, 5, and 6 and the losses in numbers of fish due to the reduction and bait fisheries, can be calculated, as well as the number of fish at each age remaining after fishing.

## RESULTS

The objective of the analysis is to calculate the numbers of fish harvested at each age in comparison to the number of fish present at each age at the beginning of a year. Age-specific exploitation rates are calculated as well as the overall exploitation rate of the commercial fisheries (reduction and bait) on the available resource.

Using the 10 year average (2004-2013) of number at age in billions of fish estimated from the base run of the BAM Model as an estimate of abundance at each age, and the ten year averages (2004-2013) for number of individual fish harvested by both the reduction and bait fisheries, the number of fish not harvested at each age, but rather “left in the water” can be calculated. The numbers of fish in both the reduction and bait fisheries are then expressed as a percentage of the number of individual fish alive at the beginning of each year to estimate an age specific exploitation rate.

**Table 1. Average number of fish from 2004-2013 listing abundance at age, reduction fishery harvest at age, bait fishery harvest at age, total harvest at age, and abundance at age not harvested (includes both the number surviving to the next age and the number lost to natural mortality.**

| Ages | Abundance | Reduction Harvest | Bait Harvest | Total Harvest | Abundance Remaining after Fishing |
|---|---|---|---|---|---|
| 0 | 15,264,300,000 | 9,494,000 | 120,000 | 9,614,000 | 15,254,686,000 |
| 1 | 5,216,100,000 | 243,092,000 | 23,240,000 | 266,332,000 | 4,949,768,000 |
| 2 | 2,286,900,000 | 447,413,000 | 78,700,000 | 526,113,000 | 1,760,787,000 |
| 3 | 870,700,000 | 90,154,000 | 47,920,000 | 138,074,000 | 732,626,000 |
| 4 | 312,300,000 | 15,842,000 | 13,780,000 | 29,622,000 | 282,678,000 |
| 5 | 148,000,000 | 929,000 | 1,440,000 | 2,369,000 | 145,631,000 |
| 6 | 171,000,000 | 0 | 80,000 | 80,000 | 170,920,000 |
| Total | 24,098,300,000 | 806,924,000 | 165,200,000 | 972,124,000 | 23,126,176,000 |

The average annual reduction fishery harvest, 806,924,000 fish, as a percentage of the starting (age-0) year class size of 15,264,300,000 fish is 5.3%

The average annual bait fishery harvest, 165,200,000 fish, as a percentage of the starting (age-0) year class size of 15,264,300,000 fish is 1.1%.

The average annual total harvest at age including both reduction and bait fisheries, 972,124,000 fish as a percentage of the starting (age-0) year class size of 15,264,300,000 is 6.4%.

| Age | Reduction Fishery Exploitation Rate | Bait Fishery Exploitation Rate | Total Exploitation Rate |
|---|---|---|---|
| 0 | 0.1% | 0.0% | 0.1% |
| 1 | 4.7% | 0.4% | 5.1% |
| 2 | 19.6% | 3.4% | 23.0% |
| 3 | 10.4% | 5.5% | 15.9% |
| 4 | 5.1% | 4.4% | 9.5% |
| 5 | 0.6% | 1.0% | 1.6% |
| 6 | 0% | <0.05% | <0.05% |

What the analysis sets out to demonstrate and what the calculations convincingly show is that the losses from fishing mortality are very small in comparison to the number of fish in the population and very small in comparison to the losses of billions of fish to natural mortality as a year class ages from 0 to 6 years of age. **From this analysis, it is evident that the reduction fishery harvested only 5.3% by number of the population each year averaged over the 2004-2013 time period, the bait fishery 1.1%, and the fishery as a whole only amounted to 6.4% of the hypothetical year class.**

Recognizing the inter-annual variability in year class strength due to environmental factors, as well as the variability of landings in any given year, five separate year classes, 2003-2007, were analyzed according to the above methods to estimate an annual exploitation rate for each year class. Each of the five year classes was followed from Age-0 through Age-6+ and the corresponding landings for those year classes were calculated to estimate an annual exploitation rate for the separate year classes. The analysis was limited to these five year classes since the terminal year of the BAM data base is 2013 and the 2008 year class, as well as those year classes that followed, could not be tracked completely through six years of landings.

**Table 2. Annual exploitation rates for five separate year classes, 2003-2007.**

| Year Class | Number of Age-0 Fish at beginning of the year | Reduction Harvest on the Year Class Over 6 Years (number of fish) | Bait Harvest on the Year Class Over 6 years (number of fish) | Year Class Exploitation Rate (based on the number of fish) |
|---|---|---|---|---|
| 2003 | 14,397,000,000 | 793,230,000 | 102,300,000 | 6.22% |
| 2004 | 15,602,000,000 | 482,880,000 | 89,800,000 | 3.67% |
| 2005 | 24,053,000,000 | 1,047,380,000 | 200,100,000 | 5.19% |
| 2006 | 16,325,000,000 | 804,080,000 | 218,100,000 | 6.26% |
| 2007 | 13,483,000,000 | 359,420,000 | 126,600,000 | 3.60% |

The estimated annual exploitation rates on the five separate year classes above ranged from 3.60% to 6.26% losses in numbers of fish, with an average annual exploitation rate of 4.99%. These estimates are of the same order of magnitude with the 6.4% exploitation rate calculated for the 10 year hypothetical year class.

## DISCUSSION

The interstate management of the Atlantic menhaden resource has always generated contentious discussions amongst fishery managers, even more so in recent years when, for the first time in 2012, a Total Allowable Catch (TAC) was implemented by the Atlantic States Marine Fisheries Commission (ASMFC) with an allocation for each Atlantic coastal State based on the average of each State's landings for the 2009-2011 period.

The analysis is designed to estimate the number of individual fish harvested by both the reduction and the bait fisheries with the balance of the individuals in a year class not taken but "left in the water". This analysis cannot partition elements of natural mortality that are attributed individually to predation, impingement and entrainment in power plants, naturally occurring fish kills, disease, or some other factor. However, with the greatest majority of natural mortality occurring on Age-0 and Age-1 year old fish, it is a fair assumption to identify predation as a major contributor to the natural mortality of these small fish.

Whatever way you wish to calculate the impact of fishing, both reduction and bait, on the size of the standing stock, the overall percentage remains very small. In this 10 year averaged approach, the total exploitation rate was only 6.4% over recent times. Yet, this very small (when viewed relative to abundance and natural mortality) amount of landings is at the heart of current Atlantic menhaden management that has become even more contentious within recent years.

## *About the Author*

*Peter Himchak has over 39 years of experience in fisheries science and management. For much of his career, Peter worked for the New Jersey Department of Environmental Protection (NJDEP), Division of Fish and Wildlife (DFW), Marine Fisheries Administration (MFA) Bureau of Marine Fisheries (BMF), where he was Supervising Fisheries Biologist at the time of his retirement in 2013. Peter also served as a member of the Atlantic Menhaden Technical Committee from 1988-2006, as well as on the Striped Bass Technical Committee from 1981- 1994. Peter currently serves as Senior Fisheries Scientist for Omega Protein and acts as a consultant to the Menhaden Fisheries Coalition.*