

ECOSYSTEM AND FISHING ALLOCATIONS OF THE ATLANTIC MENHADEN RESOURCE

An analysis by the Menhaden Fisheries Coalition

This analysis calculates the percentage of a year class that is lost to natural mortality, i.e. the ecosystem allocation, compared to the percentage of a year class that is harvested by the reduction, bait, and recreational fisheries combined, i.e. the fishing allocation. The allocations, ecosystem and fishing change dramatically as a year class ages from Age-0 to Age-1 and then again from Age-1 to Age-2. The Age-0 and Age-1 portions of the year class are referred to as the unharvested portion of the year class since all fisheries combined take so few fish of these two ages. Additionally, the ecosystem and fishing allocations also change dramatically for the harvestable portion of the population, Age-2 through Age-6+, but there is more variability as the number of fish surviving to Age-2 is dependent on the year class strength at Age-0.

However, regardless of the size of a year class as measured in billions of Age-0 fish, the ecosystem allocation, especially for the Age-0 and Age-1 fish, dwarfs the fishery allocation. While the fishery allocation increases substantially for Age-2 through Age-6+ fish, the ecosystem allocation on harvestable portion of the year class still takes the majority of these older fish. The target and threshold reference points on fishing mortality that guide the management process is based on the harvest of Age-2 to Age-4 year old fish that comprise most of the landings.

The analysis shows that regardless of the size of a year class in terms of numbers of Age-0 fish at the start of a year, the ecosystem and fishing allocations are very similar as the age class moves from the unharvested portion of the year class, Age-0 and Age-1 fish, through the harvested portion of the year class, Age-2 through Age-6+ fish.

On average, 92% of an Atlantic menhaden year class is lost to natural mortality, i.e. the ecosystem allocation, compared to the 8% of the year class that is harvested by fisheries, i.e. the fishery allocation.

DATA SOURCES

To conduct the analysis on ecosystem and fishery allocations, three data sets are required. The first data set is the number at age in billions of fish each year in order to follow an age class as it ages from 0 through 6+. These data are presented in Table 6.2.3.1 (see below), representing the most recent 10 years of data from the Atlantic States Marine Fisheries Commission’s (ASMFC) 2017 stock assessment update.

Table 6.2.3.1 Number at age in billions of fish estimated from the base run of the BAM Model, 2007-2016

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+
2007	9.756	3.128	2.143	0.423	0.086	0.037	0.016
2008	12.369	3.181	1.285	0.702	0.131	0.033	0.028
2009	9.561	4.033	1.319	0.445	0.233	0.054	0.033
2010	18.654	3.117	1.644	0.429	0.157	0.103	0.048
2011	11.411	6.081	1.246	0.475	0.126	0.061	0.081
2012	8.517	3.72	2.457	0.376	0.131	0.045	0.076
2013	9.936	2.777	1.546	0.872	0.114	0.048	0.068
2014	10.791	3.24	1.163	0.582	0.338	0.053	0.066
2015	8.781	3.519	1.336	0.398	0.209	0.15	0.066
2016	13.363	2.863	1.436	0.428	0.126	0.084	0.116

*Source: Atlantic Menhaden Stock Assessment Update, August 2017, Prepared by the ASMFC Atlantic Menhaden Stock Assessment Subcommittee.

The two other data sets required for the analysis and calculations of ecosystem and fishery allocations are the landings at age for each year class. Reduction landings at age and bait landings, that also now include recreational landings, are presented below.

Reduction landings in millions of fish

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+	Total
2007	1.1	239.2	609.3	69.5	13	0.7	0	932.8
2008	7.9	52.3	394.9	106.6	14.7	1	0	577.4
2009	4.4	352.4	229	130.8	19.9	1.8	0	738.3
2010	15.5	409.5	501.1	68.1	28.3	0.6	0	1023.1
2011	0	418.4	493	65.2	8.8	1.7	0	987.1
2012	4.7	127.3	626.9	33.6	3.9	0	0	796.4
2013	22.1	240	284.8	76.3	10.1	0.3	0	633.6
2014	3.9	268	273.2	94.7	30.3	1.6	0	671.7
2015	0	93.3	551.2	91.5	9.3	0	0	745.3

2016 12.5 180.5 347.1 162.9 8 0 0 711
 *Source: Personal Communication, NMFS Staff, Beaufort Laboratory, Population Dynamics Branch, Beaufort, NC.

Bait landings in millions of fish

Year	Age-0	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6+	Total
2007	0	35.1	112.2	34	8.1	0.5	0.1	190
2008	0	3.5	95.7	53.3	11.1	1.4	0	165
2009	0.3	23.9	47.5	60.1	12.9	1	0	145.7
2010	0	31.1	75.9	37.6	19.6	2	0.2	166.4
2011	0	40.9	69.2	61.1	36.6	4.8	0	212.6
2012	0	10.4	156.8	65.5	16.7	1.1	0.3	250.8
2013	0.9	60.6	44.8	46.1	10.6	1.7	0	164.7
2014	0	59.8	37.9	13.1	7.9	0.1	0	118.8
2015	0	26.7	76.1	10.4	2.1	0.2	0	115.5
2016	0	26.2	41.3	31.4	3.2	0.4	0	102.5

*Source: Personal Communication, NMFS Staff, Beaufort Laboratory, Population Dynamics Branch, Beaufort, NC.

CALCULATION OF NATURAL MORTALITY AT EACH AGE

Natural mortality at each age for Age-0, Age-1, and Ages 2 through 6+ was calculated in the following manner.

N_{0, 1, and 2} = number of fish beginning the year at Age 0, 1, and 2

M_{0, 1, and 2-6+} = number of fish lost to natural mortality at Age 0, 1, and 2 through 6+

F_{0, 1, and 2-6+} = number of fish harvested at Age 0, 1, and 2 through 6+ (All fisheries are included, reduction, bait, and recreational)

The estimate of losses due to natural mortality at each age is calculated by adding the fishery losses at that age with the number of individuals alive at the start of the succeeding year and subtracting that sum of individuals from the number of individuals that were alive at the beginning of the previous year. All fish in a year class from ages 2 through 6+ are combined as the harvestable portion of the year class.

$$M_0 = N_0 - (F_0 + N_1)$$

$$M_1 = N_1 - (F_1 + N_2)$$

$$M_{2 \text{ through } 6+} = N_2 - (F_{2 \text{ through } 6+})$$

Note: we can compute the natural mortality on age 2+ in both number and percentages of fish because the end result is that at some age the year class has expired. Assessment documents for Atlantic menhaden include a category Age-6+ because so few fish are detected older than 6 years of age.

THE THREE YEAR CLASSES INCLUDED IN THIS ANALYSIS

To get across the different orders of magnitude between the ecosystem and the fishery (reduction, bait, and recreational) allocations, our efforts should be directed to distinguish between the relatively non-harvested portion of the year class (ages 0 and 1) on which the ecosystem depends and the harvestable portion of the year class (2+ fish) that supports fisheries and also contributes to the ecosystem.

To demonstrate that ecosystem and fishery allocations are relatively constant regardless of the size of a year class, three of the ten year classes from the time period, 2007-2016 were selected. The highest number of Age-0 fish in a year class was in 2010, 18,654 million fish. The medium number of Age-0 fish was in 2011 with 11,411 million fish. And for the low year class, 2009 was selected because it could be followed through age-6+. The 2009 year class had 9,561 million age-0 fish.

2010 Year Class, HIGH

AGE	0	1	2+
N*	18,654	6,081	2,457
F*	15 (0.1%)	459 (7.5%)	944 (38.4%)
M*	12,558 (67.3%)	3,165 (52.0%)	1,513 (61.6%)
*All numbers in the table above are in millions of fish.			

2011 Year Class, MEDIUM

AGE	0	1	2+
N*	11,411	3,720	1,546
F*	0 (0%)	138 (3.7%)	449 (29%)
M*	7,691 (67.4%)	2,036 (54.7%)	1,097 (71%)
*All numbers in the table above are in millions of fish.			

2009 Year Class, LOW

AGE	0	1	2
N*	9,561	3,117	1,246
F*	5 (0.1%)	441 (14.1%)	684 (55%)
M*	6,439 (67.3%)	1,430 (45.9%)	562 (45%)
*All numbers in the table above are in millions of fish.			

The following table summarizes the ecosystem and fishery allocations for the year classes 2010, 2011, and 2009, listing ecosystem and fishery allocations for both Age-0 and Age-1 fish and shows the number of fish in each of the 3 year classes surviving to Age-2.

Allocations	Data (%)	Mean Value (%)
Ecosystem (age-0)	67.3 (H), 67.4 (M), 67.3(L)	67.3%
Ecosystem (age-1)	52 (H), 54.7 (M), 45.9 (L)	50.9%
Fishery (age-0)	0.1 (H), 0 (M), 0.1 (L)	0.1%
Fishey (age-1)	7.5 (H), 3.7 (M), 14.1 (L)	8.4%
Surviving to age-2	13.2 (H), 13.5 (M), 13.0 (L)	13.2%

For the harvestable portion of the year class, ages 2+, the fishery allocation is significantly larger, but the ecosystem allocation still remains relatively high as a percentage of the older fish susceptible to fishing.

Number of 2+ Fish	Ecosystem Allocation	Fisheries Allocation
2,457 (H)	61.6%	38.4%
1,546 (M)	71%	29%
1,246 (L)	45%	55%

Mean Ecosystem Allocation is 59.2% and the mean fishery allocation is 40.8%.

DISCUSSION AND CONCLUSION

The blue shaded table below summarizes all the percent allocations for the three year classes by age. The mean value for all the percent allocations is calculated to support the infographic that accompanies this paper.

For Age-0 fish, the ecosystem allocation is remarkably constant at 67.3% for the three different year classes that differ substantially in the number of Age-0 fish that comprised the year class. Equally remarkable is the constant fishery allocation on the three year classes that averages only 0.07%. For Age-1 fish, the ecosystem allocation is 50.9% and the fishery allocation is 8.4%, on average.

For the Age 2 through 6+ year old fish, there is some variation in both the ecosystem allocation and the fishery allocation but, on average, the ecosystem still takes many more fish, 59.2%, versus the fishery allocation, on average 40.8%, that are exposed to fishing pressure.

So, how does one defend the statement that, on average, 92% of an Atlantic menhaden year class is lost to natural mortality, i.e. the ecosystem allocation, compared to the 8% of the year class that is harvested by fisheries, i.e. the fishery allocation? Consider 1,000 Age-0 fish starting out as the year class and 67.3% are lost to the ecosystem and 0.07% are lost to the fishery. That equates to a loss of 673 fish to the ecosystem and 1 fish lost to the fishery. There are now only 326 fish starting out as Age-1 fish and of those Age-1 fish, 166 are lost to the ecosystem allocation and 27 are lost to the fishery allocation which leaves only 133 of the original year class Age-0 fish surviving to Age-2. The ecosystem takes 79 of the 133 surviving fish and the fishery takes 54 of these older fish. It is now simple math to add up all the ecosystem losses, $673 + 166 + 79 = 918/1,000 = 91.8\%$. The fishery losses at age are $1 + 27 + 54 = 82/1,000 = 8.2\%$.

	Unharvestable Portion				Harvestable Portion	
	Age-0		Age-1		Ages 2-6+	
Allocations	Ecosystem	Fishery	Ecosystem	Fishery	Ecosystem	Fishery
Year Class 2010 18.654*	67.3	.01	52.0	7.5	61.6	38.4
2011 11.411*	67.4	0.0	54.7	3.7	71.0	29.0
2009 9.561*	67.3	0.1	45.9	14.1	45.0	55.0
Mean %	67.3	0.07	50.9	8.4	59.2	40.8