2001 STATUS OF ATLANTIC MENHADEN STOCK AND FISHERY

Report of the Atlantic Menhaden Technical Committee

July 1, 2001

1. Executive Summary

The Atlantic Menhaden Technical Committee met in Richmond, Virginia on May 30 - 31, 2001 to assess the current status of the Atlantic menhaden with a focus on the new benchmarks in Amendment I, review IWP applications, consider recent state management actions, and formulate management recommendations to the Atlantic Menhaden Management Board.

Landings in the Atlantic menhaden reduction fishery during 2000 (167,253 mt) continued a declining trend in this fishery statistic in recent years, which is primarily due to decreased size in the fishing fleet and limited processing capacity of the two remaining plants. The NMFS forecast for reduction landings in 2001 predicted similar levels of fishing effort and landings this year as occurred in 2000.

Concurrently, as reduction fishing effort and landings decline, Atlantic menhaden bait landings are becoming increasingly more important. On a coastwide basis, bait landings accounted for approximately 16 percent of the total combined bait and reduction landings in 2000, up from 10 percent in recent years. As the bait fisheries take a more significant portion of the Atlantic menhaden harvest, the importance of tracking and monitoring this segment of the fishery becomes a higher priority. More reliable landings data and continuation and expansion of the biostatistical sampling program are needed for the menhaden bait fishery along the Atlantic coast.

Following the recent period of poor recruitment to age-1 (below 2 billion for 1996 - 2000; based on the Murphy VPA approach applied to reduction data only), the Spawning Stock Biomass (SSB) has decayed from recent high levels to below the historical median. The concern about recent poor recruitment is further substantiated by investigations with state-based juvenile abundance indices and development of a coastwide index. Recruitment of Atlantic menhaden has been low recently, despite a high level of SSB. It appears that recruitment was poor due to environmental conditions rather than the lack of SSB. Consequently, seeking to increase spawning stock biomass is not likely to improve the situation by itself.

One of the most important discussions of the Technical Committee was centered around the question of how to use the bait landings data (1985 - 2000). The entire committee strongly supported utilizing a combination of reduction and bait fisheries data for the Atlantic menhaden stock assessment analyses, and to recommend revising the overfishing definition in Amendment I to reflect this action. Because the bait fishery tends to harvest older and larger menhaden, the combined catch-at-age matrix implies that more older and larger fish were removed relative to the younger and smaller fish. By relying solely on the reduction fishery landings, the previous assessments appear to contain some level of bias. Since the older fish were under-represented, the previous assessments underestimated the abundance of older fish. Using the combined reduction and bait fishery data would remove any bias inherent in relying on the reduction fishery data only, and provide a more accurate picture of the total menhaden population.

The benchmarks for fishing mortality (F) and SSB were reviewed, with reduction data only and also with the incorporation of the bait data. With the addition of bait data to these analyses, the status of F and SSB in 2000 suggest that fishing mortality rate is well below the F-target and SSB is well above the SSB-target (either based on benchmarks from Amendment I or on re-calculated benchmarks). However, only slight improvement is noted in recent estimates of recruits to age-1, with the most recent estimates for 1999 and 2000 very low. With recent low values for juvenile abundance indices from the Chesapeake Bay, this region appears to be the epicenter for poor survival to age 1. There is no evidence that the recent low levels of recruitment were caused by overfishing. Only the occurrence of one or more

moderate to strong recruitment year classes will prevent the continuing deterioration from recent high levels of spawning stock biomass to lower levels.

2. Landings by Sector

Landings of Atlantic menhaden for reduction in 2000 amounted to 167,253 metric tons (Table 2.3). This was 2% less than the purse-seine landings for 1999 (171,191 t), and 36% less than the average landings for the previous five years (261,820 t). As in 1998 and 1999, two menhaden factories operated on the Atlantic coast in 2000, one in Reedville, Virginia, and one in Beaufort, North Carolina. Unlike the previous two years however, only 12 vessels (ten in Reedville and two in Beaufort) regularly unloaded Atlantic menhaden for reduction in 2000, versus 15 vessels in 1998 and 1999. Nominal or observed fishing effort in the Atlantic menhaden reduction fishery has steadily declined in recent years from 616 vessel weeks in 1997, to 437 vessel weeks in 1998, and 382 vessel weeks in 1999. Nominal fishing effort for the 12 active reduction vessels in 2000 was 311 vessel weeks.

In 2001, two menhaden reduction factories will operate with a total of twelve vessels. Based on the historical performance of these vessels, it is estimated that nominal fishing effort in 2001 will be about 321 vessel weeks. At this level of fishing effort, the NMFS forecast for Atlantic menhaden reduction landings in 2001 is 191,000 t, with 80% confidence levels of 119,000 and 262,000 t.

Coastwide landings for bait in 2000 are estimated at 31,800 t, or 16% of the total combined bait and reduction landings of Atlantic menhaden. The major portion of bait landings in recent years has been harvested from New Jersey and Virginia waters, followed by Maryland, North Carolina, Florida and the Potomac River. Through the period 1985-1997, bait landings generally comprised about 10% or less of the total Atlantic menhaden harvest. With the decline in the reduction landings over the last three years, the relative importance of the bait fishery has increased (see Table 3.1 in Vaughan et al. 2001).

3. Analytical Assessment

NOAA Fisheries's Center for Coastal Fisheries and Habitat Research (Beaufort Laboratory) has conducted coastwide biological sampling of Atlantic menhaden for length and weight at age since 1955, developing one of the longest and most complete time series of biostatistical fishery data in the nation (Table 2.2 in Vaughan et al. 2001). Biological sampling is based on a two-stage cluster design, and it has been conducted over the range of the reduction fishery, both temporally (weekly) and geographically (port). The catch-at-age matrix for Atlantic menhaden landed for reduction is one of the most accurate and precise catch matrices used in the U.S. (Table 2.3 in Vaughan et al. 2001). Bait landings of Atlantic menhaden are available since 1985. Because of limited age composition data, bait landings were separated into the three geographic areas (New England; Middle Atlantic and Chesapeake Bay including coastal Virginia waters; and South Atlantic). Length frequency distributions and age-length keys for the summer period were developed by area in three-year increments from 1989-2000 to convert bait landings to catch in numbers at age. Hence, catch-at-age estimates from the reduction fishery were combined with catch-at-age estimates from the bait fishery to create a combined Atlantic menhaden catch-at-age matrix for the period 1985-2000 (Table 3.4 in Vaughan et al. 2001).

The Murphy virtual population analysis (VPA) approach has been applied to Atlantic menhaden for many years. This method does not provide for calibration to fishery independent surveys, although preliminary runs have been made of a calibration approach based on a forward projection model implemented by AD Model Builder (Appendix B in Vaughan et al. 2001). The Murphy VPA has been conducted on the reduction catch matrix only and on the reduction and bait catch matrices combined. Because the benchmarks developed in Amendment 1 were based on Murphy VPA output from reduction data only, alternate benchmarks were estimated based on Murphy VPA output from the reduction and bait data combined. Estimates of fishing mortality (full F), recruits to age-1 (R1), and spawning stock biomass (SSB) were obtained from the Murphy VPA applied to the two catch matrices (summarized with current value, 25th, 50th, and 75th percentiles in Table 5.1 of Vaughan et al. 2001). In general, estimates from VPAs are most uncertain in the terminal (most recent) year.

Fishing mortality rates on fully recruited ages (referred to as full F) are calculated as the weighted average of age-specific F's for ages 2-8, weighted by catch in numbers (Figures 2.5 and 3.1 in Vaughan et al. 2001). Both temporal series show a downward trend in full F since the early 1970s. Preliminary estimates for 2000 are F = 1.1 based on reduction catch matrix only and F = 0.6 based on reduction and bait catch matrices combined. In the former case, current F is at approximately its 25th percentile of the 46-year set of estimates, while in the latter case current F is well below its 25th percentile.

Low estimates of recruits to age-1 (Figures 2.7 and 3.2 in Vaughan et al. 2001) have been of particular concern in recent years. Recruitment of Atlantic menhaden to age-1 was high during the late 1950s, with the record high recruitment estimated at 15.1 billion recruits in 1959 (the 1958 year class). Recruitment was generally poor during the 1960s, high recruitment occurred during the 1970s and 1980s, followed by declining recruitment during the 1990s. Preliminary estimates in 2000 are R_1 = 0.8 billion based on reduction catch matrix only and R_1 = 1.2 billion based on reduction and bait catch matrices combined. In both cases current R_1 is well below its 25th percentile of the 46-year set of estimates. However, the most recent estimate of recruitment (terminal year - 2000) has the greatest uncertainty, and the estimate for 2000 is likely to change considerably as more data from that cohort (age-1 in 2001, age-2 in 2002, etc.) are added to the analysis. Historically, initial low estimates of recruits have increased as additional years of data are acquired, while initial high estimates have declined (Cadrin and Vaughan 1997)

Historical trends in spawning stock biomass (SSB) have shown considerable variability over the 46-year period (Figures 2.8 and 3.3 in Vaughan et al. 2001). Extremely large values of SSB were present during the late 1950s and early 1960s, resulting primarily from two very large year classes (1951 and 1958). With mostly poor recruitment during the 1960s, SSB declined to low levels. Rebuilding of the SSB occurred during the 1970s and 1980s when recruitment was good to excellent, and SSB recently peaked in 1997. Preliminary estimates in 2000 are SSB = 33,200 t based on the reduction catch matrix only and SSB = 90,100 t based on the reduction and bait catch matrices combined. In the former case current SSB lies above its 25th percentile and below the median (50th percentile) of the 46-year set of estimates, while in the latter case current SSB is above its 75th percentile.

We define an index of relative survival (S_o) as the ratio of recruits to age-1 (R_1) to the spawning stock biomass (SSB) that produced them. Relative survival from spawning stock biomass to subsequent recruits to age-1 was estimated for 1955-1999 (year associated with SSB) as:

$$S_o = R_1/SSB.$$

This index permits one to judge the relative survival from egg production (assuming proportionality with female biomass) and subsequent recruitment to age-1. The temporal pattern of this index shows generally low survival during the late 1950s and early 1960s (generally very high SSB), with the exception of the 1958 year class (Figure 4.2 in Vaughan et al. 2001). A particularly high index of relative survival was estimated during the mid-1970s, aiding in the rebuilding of the menhaden stock. Only in recent years has the index of relative survival been very low, on par with the 1950s and early 1960s (with the exception of the 1958 year class).

The most recent values of standardized state juvenile abundance indices are compared with their median and interquartile range (Table 5.1 in Vaughan et al. 2001). The juvenile abundance indices from North Carolina, Virginia and Maryland are all below their 25th percentile. The indices from Chesapeake Bay (Maryland and Virginia) have been low for some time, while the North Carolina indices showed a recent decline, possibly due to several hurricanes during the previous fall. The SEAMAP indices for ages 1 and 2 are between their median and 75th percentiles. The juvenile abundance indices from Connecticut and Rhode Island are well above their 75th percentiles. The coastwide index (North Carolina through southern New England) falls just above its 25th percentile.

4. Biological Reference Points/Status of Stock

Stock size and fishing mortality were estimated utilizing the Murphy VPA for two data sets, one with just the reduction fishery landings, and one that combined the reduction and bait landings into a combined catch at age matrix. The reference points contained in Amendment 1 were then recalculated based on the combined data.

Reduction Data Only

Based on a catch-at-age matrix for the reduction fishery data only, the VPA-generated estimate of fishing mortality for 2000 (F_{2000} = 1.1 year^{-1}) was below the overfishing threshold (F = 1.33), and slightly above target (F = 1.04) reference points contained in Amendment 1. The estimate of spawning stock biomass (SSB_{2000} = 33,200 t) was above the threshold (20,570 t), but below the target (37,400 t) values. The Technical Committee's interpretation of the reference points is that a fishing mortality rate greater than the threshold level would constitute an overfishing condition, while an SSB level below the threshold value would define a depleted stock condition. Therefore, based on the biological reference points in Amendment 1, the Atlantic menhaden population is not overfished and overfishing is not occurring. Given the variability and error in terminal year estimates generated by a VPA, the Technical Committee considers the difference between the F_{2000} level is very likely to be indistinguishable from the target F value. The spawning stock biomass is in decline due to a series of years with poor recruitment (to age-1). There is no evidence to suggest that the recent low levels of recruitment have been caused by overfishing. The poor recruitment appears to be the result of poor survivorship of age-0 fish prior to their entry into the fishery at age-1. If recruitment does not improve in the near term, spawning stock biomass may decline further and approach the threshold level in the future.

Combined Reduction and Bait Fishery Data

Based on a combined catch at age matrix, the VPA-generated estimate of fishing mortality for 2000 (F_{2000} = 0.6 year^{-1}) was below both the revised overfishing threshold (F = 1.1) and target (F = 0.9). The estimate of spawning stock biomass (SSB_{2000} = 90,100 t) was above both the revised threshold (27,500 t) and target (50,000 t) values. Based on the revised biological reference points, the Atlantic menhaden population is not overfished and overfishing is not occurring. However, the spawning stock biomass is

declining due to a series of years with poor recruitment (to age-1). There is no evidence that recent low levels of recruitment have been caused by overfishing. The poor recruitment appears to be the result of poor survivorship of age-0 fish prior to their entry into the fishery at age-1. If recruitment does not improve in the near term, spawning stock biomass may decline below the target and threshold levels in the future.

The Technical Committee recommends that future stock assessments be based on the combined reduction and bait fishery data. Due to the decline in reduction fishery landings coupled with increased and improved reporting of the bait fishery landings, the relative importance of the bait fishery landings has increased. Because the bait fishery tends to harvest older and larger menhaden, the combined catch at age matrix (Table 3.4) implies that more older and larger fish were removed relative to the younger and smaller fish. By relying solely on the reduction fishery landings, the previous assessments appear to contain some level of bias. Since the older fish were under-represented, the assessments underestimated the abundance of older fish. Using the combined reduction and bait fishery data would remove any bias inherent in relying on the reduction fishery data only, and provide a more accurate picture of the total menhaden population.

As a result of this recommendation, new biological reference points based on the combined data have been calculated (see below). ***The Technical Committee recommends that the Management Board adopt these new reference points for managing the Atlantic menhaden resource.*** Commission staff will look into whether this can be accomplished through either incorporation into the current amendment by Board action at its July meeting, or whether a technical addendum can be prepared for this purpose. If neither of these are appropriate for modifying the overfishing definition contained in Amendment 1, an addendum under the provisions for Adaptive Management (*Section 4.6*), should be prepared to accomplish this as soon as possible.

Reference Point	**"Old"**	**"New"**	**Stock Status**
Fishing Mortality Target (F_{target})	1.04	0.9	0.6
Fishing Mortality Threshold ($F_{threshold}$)	1.33	1.1	
Spawning Stock Biomass Target (SSB_{target})	37,400 mt	50,000 mt	90,100 mt
Spawning Stock Biomass Threshold ($SSB_{threshold}$)	20,570 mt	27,500 mt	

5. State Actions

New Jersey - On July 13, 2000 the New Jersey Marine Fisheries Council, by majority vote, passed a motion to prohibit the taking of Atlantic menhaden by any means for purposes of fish meal reduction. The Department of Environmental Protection subsequently developed proposed amendments to N.A.J.C. 7:25-22 prohibiting the taking of Atlantic menhaden by any means for fish meal reduction to eliminate the potential for the harvesting of Atlantic menhaden on such a large scale as could occur if the market for fish meal and other reduction products experienced major expansion, or if the purse seine fleet for reduction purposes were to move a greater proportion of their harvesting effort from Virginia waters to more northerly areas, including New Jersey. A public hearing held February 20, 2001 elicited many comments for and against the adoption of the proposed amendments. On March ,2001, the Marine Fisheries Council, by

majority vote, vetoed the proposed amendments to N.J.A.C. 7:25-22 and they were not adopted.

Following the March 8, 2001 Marine Fisheries Council meeting, several bills were introduced into the State legislature to prohibit the taking of Atlantic menhaden in State coastal waters for fish meal reduction. On June 7, 2001, Menhaden Bill S2252/A3512 was voted out of the Agriculture and Natural Resources Committee. This Bill must now be voted upon by the State Assembly and Senate.

Connecticut - In April 2000, all purse seine fishing was prohibited in state waters for all species.

6. IWP Applications

No applications for Internal Waters Processing operations were received.

7. Recommendations to the Atlantic Menhaden Management Board

The following recommendations address research and data needs that should enhance the ability to evaluate the status of the menhaden population in addition to those identified and listed in the annual Atlantic Menhaden FMP Review.

Management Recommendations

1. Revise the overfishing definition in Amendment 1 to incorporate data from bait fisheries.

Research and Data Needs

1. A better characterization of each state's bait fishery, with regards to gear-specific age, size compositions and catch locations, with emphasis on Maryland, Florida and PRFC.

2. Initiate studies of young-of-year Atlantic menhaden in the nursery areas; identify and evaluate biotic and abiotic factors that may influence survivorship.

3. Request that states review sampling programs and develop or improve fishery independent indices of juvenile and adult menhaden abundance.

4. Initiate a study of current social and economic aspects of the Atlantic menhaden fishery, and markets of domestic and international products.

5. Initiate studies to quantify predation on menhaden by principal predators such as striped bass and bluefish, and improve estimate of natural mortality rate and its interannual variation.

8. Elections/Appointments

Ellen Cosby was elected Chair and Dr. Michael Armstrong was elected as the Vice-chair of the Technical Committee. The committee nominated Mike Armstrong, Behzad Mahmoudi, Alexei Sharov, and Joe Smith to serve as members of the Menhaden Stock Assessment Subcommittee which would be chaired by Doug Vaughan ***(staff note: subcommittee membership should be formally approved by the Management Board)***.

Table 2.2 Atlantic menhaden sample size (n), landings in numbers of fish, landings in biomass (C), and sampling intensity (landings in metric tons per 100 fish measured), 1955-2000.

Year	Sample Size (n)	Landings (millions of fish)	Landings (1000 t)	Intensity (C/100n)
1955	16136	3118.4	641.4	3875.0
1956	19875	3564.8	712.1	3582.9
1957	19698	3511.7	602.8	3060.2
1958	15324	2719.2	510.0	3328.1
1959	17960	5353.6	659.1	3669.8
1960	13513	2775.1	529.8	3920.7
1961	13189	2598.3	575.9	4366.5
1962	15733	2099.9	537.7	3417.7
1963	13033	1764.5	346.9	2661.7
1964	10443	1729.1	269.2	2577.8
1965	19550	1519.5	273.4	1398.5
1966	15670	1340.6	219.6	1401.4
1967	15435	984.2	193.5	1253.6
1968	26838	1148.0	234.8	874.9
1969	15081	868.2	161.6	1071.5
1970	8435	1400.5	259.4	3075.3
1971	8269	969.1	250.3	3027.0
1972	6553	1713.9	365.9	5583.7
1973	6353	1843.4	346.9	5460.4
1974	5421	1990.6	292.2	5390.1
1975	7283	2162.3	250.2	3435.4
1976	6725	3283.5	340.5	5063.2
1977	7276	3673.7	341.1	4688.0
1978	7094	3085.2	344.1	4850.6
1979	6366	3870.1	375.7	5901.7
1980	7291	3332.3	401.5	5506.8
1981	9191	3984.0	381.3	4148.6
1982	9066	3175.7	382.4	4218.0
1983	11228	3942.1	418.6	3728.2
1984	11689	3548.0	326.3	2791.5
1985	7700	3025.3	306.7	3983.1
1986	5408	1912.4	238.0	4400.9
1987	7398	2315.2	327.0	4420.1
1988	7339	2158.0	309.3	4214.5
1989	6877	2630.5	322.0	4682.3
1990	7029	2157.9	401.2	5707.8
1991	7690	3166.6	381.4	4959.7
1992	5600	2052.5	297.6	5314.3
1993	5318	1594.0	320.6	6028.6
1994	4708	1492.1	260.0	5522.5
1995	4606	1643.3	339.9	7379.5
1996	4218	1091.9	292.9	6944.0
1997	4115	995.9	259.1	6296.5
1998	3808	1007.5	245.9	6457.5
1999	3600	1056.3	171.3	4758.3
2000	2940	657.4	167.3	5690.5

Table 2.3 Estimated Atlantic menhaden landings in numbers by age (millions) and weight of total

landings (thousands of metric tons), 1955-2000 (estimates for 2000 are preliminary).

Year	Number at age							Total number	Total weight
	0	1	2	3	4	5	6-8		
1955	761.0	674.1	1057.7	267.3	307.2	38.1	13.0	3118.4	641.4
1956	36.4	2073.3	902.7	319.6	44.8	150.7	37.4	3564.8	712.1
1957	299.6	1600.0	1361.8	96.7	70.8	40.5	42.3	3511.7	602.8
1958	106.1	858.2	1635.3	72.0	17.3	15.9	14.4	2719.2	510.0
1959	11.4	4038.7	851.3	388.3	33.4	11.9	18.7	5353.6	659.1
1960	72.2	281.0	2208.6	76.4	102.2	23.8	11.0	2775.1	529.8
1961	0.2	832.4	503.6	1209.6	19.2	29.4	3.9	2598.3	575.9
1962	51.6	514.1	834.5	217.3	423.4	30.8	28.3	2099.9	537.7
1963	96.9	724.2	709.2	122.5	45.0	52.4	14.3	1764.5	346.9
1964	302.6	704.0	605.0	83.5	17.9	7.8	8.3	1729.1	269.2
1965	259.1	745.2	421.4	77.8	12.2	1.8	2.0	1519.5	273.4
1966	349.5	550.8	404.1	31.7	3.9	0.4	0.3	1340.6	219.6
1967	7.0	633.2	265.7	72.8	5.1	0.5	0.0	984.2	193.5
1968	154.3	377.4	539.0	65.7	10.7	1.0	0.1	1148.0	234.8
1969	158.1	372.3	284.3	47.8	5.4	0.1	0.0	868.2	161.6
1970	21.4	870.8	473.9	32.6	4.0	0.1	0.0	1403.0	259.4
1971	72.8	263.3	524.3	88.3	17.8	2.5	0.0	969.1	250.3
1972	50.2	981.3	488.5	173.1	19.1	1.9	0.0	1713.9	365.9
1973	56.0	588.5	1152.9	38.6	7.0	0.3	0.0	1843.4	346.9
1974	315.6	636.7	986.0	48.6	2.5	1.4	0.0	1990.6	292.2
1975	298.6	720.0	1086.5	50.2	6.6	0.2	0.1	2162.3	250.2
1976	274.2	1612.0	1341.1	48.0	8.0	0.3	0.0	3283.5	340.5
1977	484.6	1004.5	2081.8	83.5	17.8	1.4	0.1	3673.7	341.1
1978	457.4	664.1	1670.9	258.1	31.2	3.5	0.0	3085.2	344.1
1979	1492.5	623.1	1603.3	127.9	21.8	1.5	0.1	3870.1	375.7
1980	88.3	1478.1	1458.2	222.7	69.2	14.4	1.4	3332.3	401.5
1981	1187.6	698.7	1811.5	222.2	47.5	15.4	1.3	3984.0	381.3
1982	114.1	919.4	1739.5	379.7	16.3	5.8	0.9	3175.7	382.4
1983	964.4	517.2	2293.1	114.3	47.4	5.0	0.7	3942.1	418.6
1984	1294.2	1024.2	892.1	271.5	50.3	15.2	0.5	3548.0	326.3
1985	637.2	1075.8	1224.6	44.1	35.6	6.2	1.7	3025.3	306.7
1986	98.4	224.2	1523.1	49.1	10.5	6.1	1.1	1912.4	238.0
1987	42.9	504.7	1587.7	151.9	25.2	2.2	0.7	2315.2	327.0
1988	338.8	282.7	1157.6	301.4	69.8	7.1	0.3	2158.0	309.3
1989	149.7	1154.6	1158.5	108.4	47.5	11.6	0.2	2630.0	322.0
1990	308.1	132.8	1553.1	109.0	42.2	12.7	0.4	2157.9	401.2
1991	881.8	1033.9	946.1	254.0	37.9	10.7	2.0	3166.6	381.4
1992	399.6	727.2	195.4	66.1	51.3	10.9	1.4	2052.5	297.6
1993	67.9	379.0	983.1	148.9	10.9	3.9	0.3	1594.0	320.6
1994	88.6	274.5	888.9	165.1	67.2	7.5	0.2	1492.1	260.0
1995	56.8	533.6	671.9	309.1	67.5	4.4	0.0	1643.3	339.9
1996	33.7	209.1	679.1	138.9	29.0	2.0	0.0	1091.9	292.9
1997	25.2	246.9	424.5	237.4	51.6	9.0	1.2	995.9	259.1
1998	72.8	185.0	540.6	126.3	73.0	9.0	0.8	1007.5	245.9
1999	193.9	301.1	450.8	81.8	25.0	3.2	0.4	1056.3	171.3
2000	77.8	114.2	340.6	111.9	11.1	1.9	0.0	657.4	167.3

Table 2.5 Estimated Atlantic menhaden population size in numbers by age (in millions) from Murphy Virtual Population Analysis, 1955-99 (estimates of population size at age-0 should be interpreted with care, because natural mortality at this age is poorly known).

Year	0	1	2	3	4	5	6	7	8
1955	7962.2	3091.4	2285.4	619.6	813.4	116.4	32.1	7.3	2.0
1956	9112.6	5680.4	1443.2	644.3	189.1	280.9	44.6	12.3	3.2
1957	4496.7	7243.4	2015.0	239.1	166.0	85.6	64.2	6.9	2.7
1958	19031.2	3324.1	3367.4	265.0	77.7	51.2	23.5	12.9	1.2
1959	2787.9	15103.1	1449.3	893.3	112.8	36.1	20.3	7.9	4.4
1960	3848.3	2216.1	6479.4	278.5	270.5	45.9	13.8	3.6	1.6
1961	2790.7	3008.7	1192.0	2417.1	118.0	93.3	11.1	2.7	0.5
1962	2853.9	2228.3	1269.3	371.7	615.0	60.2	36.7	4.8	1.1
1963	2288.8	2232.9	1018.9	182.5	72.2	75.8	14.9	5.0	0.8
1964	2729.0	1741.2	860.9	120.3	24.5	12.1	9.2	1.7	0.7
1965	1997.5	1910.1	566.4	98.0	14.4	2.3	1.8	0.9	0.1
1966	2810.5	1373.6	641.8	49.6	5.7	0.4	0.2	0.3	0.1
1967	1491.5	1933.5	450.4	104.4	7.7	0.7	0.0	0.0	0.1
1968	2278.0	1184.8	740.7	85.7	12.3	1.1	0.1	0.0	0.0
1969	3397.8	1681.7	462.1	72.4	6.3	0.2	0.0	0.0	0.0
1970	1690.1	2572.3	780.8	79.8	10.3	0.1	0.0	0.0	0.0
1971	4383.0	1330.5	964.0	139.4	25.7	3.4	0.0	0.0	0.0
1972	3426.4	3435.1	642.2	215.0	22.3	3.1	0.3	0.0	0.0
1973	3812.5	2691.5	1425.9	49.6	11.0	0.6	0.6	0.2	0.0
1974	5042.4	2994.4	1255.4	70.2	3.3	1.8	0.1	0.4	0.1
1975	8850.7	3745.2	1410.8	78.4	8.5	0.3	0.1	0.1	0.2
1976	6724.6	6801.3	1823.7	100.8	12.2	0.5	0.0	0.0	0.0
1977	6414.9	5125.1	3076.0	169.4	27.4	1.8	0.1	0.0	0.0
1978	5787.0	4691.0	2480.4	402.9	44.1	4.1	0.1	0.0	0.0
1979	9987.1	4213.8	2469.1	329.9	62.6	4.9	0.1	0.1	0.0
1980	5948.1	6648.1	2197.0	368.8	111.4	23.0	2.0	0.0	0.0
1981	9277.0	4671.0	3082.0	306.7	66.6	18.7	3.8	0.2	0.0
1982	3188.8	6352.2	2429.4	591.8	30.6	7.2	0.8	1.5	0.1
1983	5817.9	2444.5	3328.2	255.6	91.6	7.0	0.4	0.1	0.7
1984	7695.8	3788.6	1153.8	408.8	75.0	22.2	0.8	0.1	0.1
1985	6295.0	4995.5	1616.5	80.5	56.9	10.1	2.8	0.1	0.0
1986	4339.5	4459.5	2342.9	127.8	17.7	9.4	1.7	0.5	0.1
1987	3788.0	3377.2	2666.6	348.6	43.5	3.4	1.4	0.3	0.3
1988	7291.4	2985.6	1757.1	497.4	105.3	8.6	0.5	0.4	0.2
1989	2943.3	5520.6	1678.0	251.0	89.2	14.8	0.4	0.1	0.1
1990	4777.2	2217.0	2477.9	224.0	76.5	20.6	0.9	0.1	0.0
1991	5424.0	3540.1	1308.8	391.3	64.6	16.6	3.8	0.2	0.0
1992	4504.3	3547.8	1452.1	132.0	65.0	12.9	2.6	0.9	0.1
1993	2974.9	3241.1	1692.6	319.9	33.6	5.1	0.6	0.6	0.2
1994	3848.4	2314.9	1768.5	333.2	89.6	12.9	0.4	0.1	0.4
1995	2014.2	2994.1	1260.0	447.2	86.0	7.5	2.5	0.1	0.1
1996	2064.8	1557.8	1490.3	290.7	54.3	5.4	1.4	1.6	0.0
1997	1991.1	1618.7	828.7	427.9	78.7	12.5	1.8	0.9	0.0
1998	1740.9	1567.4	838.1	203.8	92.0	11.4	1.3	0.3	0.6
1999	1259.8	1325.2	853.7	127.7	34.5	5.3	0.7	0.3	0.2
2000	6030.5	833.6	609.3	200.1	19.8	3.5	1.0	0.2	0.2

Table 3.1 Comparison of landings (1000 t) by the bait and reduction fisheries for Atlantic menhaden (preliminary bait data for 2000, average for 1998-1999 used in absence of available estimates).

Year	Reduction	Bait (%)	Total
1985	306.7	26.7 (8.0)	333.4
1986	238.0	28.0 (10.5)	266.0
1987	326.9	30.6 (8.6)	357.5
1988	309.3	36.3 (10.5)	345.6
1989	322.0	30.9 (8.8)	352.9
1990	401.2	30.7 (7.1)	431.9
1991	381.4	36.2 (8.7)	417.6
1992	297.6	38.7 (11.5)	336.3
1993	320.6	35.1 (9.9)	355.7
1994	260.0	28.1 (9.8)	288.1
1995	339.9	31.1 (8.4)	371.0
1996	291.5	23.3 (7.4)	314.8
1997	259.1	25.6 (9.0)	284.7
1998	245.9	39.1 (13.7)	285.0
1999	171.3	35.9 (17.3)	207.2
2000	167.3	31.8 (16.0)	199.1

Table 3.2 Catch in numbers at age for the Atlantic menhaden reduction landings (in millions) (preliminary 2000 data).

Year	N0	N1	N2	N3	N4	N5	N6-8	Total
1985	637.2	1075.9	1224.6	44.1	35.6	6.3	1.7	3025.3
1986	98.4	224.2	1523.1	49.1	10.5	6.1	1.1	1912.4
1987	42.9	504.7	1587.7	151.9	25.2	2.2	0.7	2315.2
1988	338.8	282.7	1157.7	301.4	69.8	7.1	0.6	2158.0
1989	149.7	1154.6	1158.5	108.4	47.5	11.6	0.2	2630.5
1990	308.1	132.8	1553.1	109.0	42.2	12.3	0.4	2157.9
1991	881.8	1033.9	946.1	254.0	37.9	10.7	2.2	3166.6
1992	399.7	727.2	795.4	66.1	51.3	10.9	1.9	2052.5
1993	67.9	379.0	983.1	148.9	10.9	3.9	0.3	1594.0
1994	88.6	274.5	888.9	165.1	67.2	7.5	0.2	1492.0
1995	56.8	533.7	671.9	309.1	67.5	4.4	0.0	1643.3
1996	33.7	209.1	679.1	138.9	29.0	2.0	0.0	1091.9
1997	25.2	246.9	424.5	237.4	51.6	9.0	1.2	995.9
1998	76.9	185.0	540.6	126.3	73.5	9.0	0.8	1007.5
1999	193.9	301.1	450.8	81.9	25.0	3.2	0.4	1056.3
2000	77.7	114.1	340.6	111.9	11.1	1.9	0.0	657.4

Table 3.3 Catch in numbers at age for the Atlantic menhaden bait landings (in millions) (preliminary 2000 data).

Year	N0	N1	N2	N3	N4	N5	Total
1985	0.0	7.0	23.8	23.2	21.2	8.0	83.2
1986	0.0	7.8	30.0	24.4	19.1	6.1	87.4
1987	0.0	8.1	30.9	26.8	21.8	7.2	94.8
1988	0.0	9.3	38.1	31.9	24.3	7.3	110.9
1989	0.0	10.6	34.7	26.3	22.8	8.2	102.6
1990	0.0	12.6	40.4	25.5	21.3	7.3	107.1
1991	0.0	10.6	38.3	31.4	25.9	8.8	115.1
1992	0.0	17.8	28.1	32.1	30.2	8.4	116.5
1993	0.0	12.2	22.6	29.3	27.5	7.6	99.2
1994	0.0	17.8	18.8	21.0	24.3	7.6	89.5
1995	0.0	13.6	13.3	42.5	27.2	1.0	97.5
1996	0.0	4.5	4.1	34.9	23.6	0.8	67.9
1997	0.0	13.6	8.6	36.6	24.7	0.9	84.4
1998	0.0	0.3	11.9	34.9	35.6	14.9	97.6
1999	0.0	0.3	11.3	32.0	32.7	13.7	90.0
2000	0.0	0.3	10.9	28.3	28.7	12.1	80.2

Table 3.4 Catch in numbers at age for the Atlantic menhaden combined reduction and bait landings (in millions) (preliminary 2000 data).

Year	N0	N1	N2	N3	N4	N5	N6-8	Total
1985	637.2	1082.9	1248.4	67.3	56.8	14.2	1.7	3108.5
1986	98.4	232.0	1553.1	73.5	29.6	12.1	1.1	1999.8
1987	42.9	512.8	1618.6	178.7	46.9	9.4	0.7	2410.0
1988	338.8	292.0	1195.7	333.3	94.1	14.5	0.6	2268.9
1989	149.7	1165.1	1193.3	134.7	70.3	19.8	0.2	2733.2
1990	308.1	145.4	1593.6	134.5	63.4	19.7	0.4	2265.0
1991	881.8	1044.6	984.4	285.4	63.9	19.5	2.2	3281.7
1992	399.7	745.0	823.5	98.1	81.5	19.3	1.9	2168.9
1993	67.9	391.2	1005.6	178.2	38.5	11.5	0.3	1693.2
1994	88.6	292.3	907.6	186.1	91.6	15.1	0.2	1581.6
1995	56.8	547.2	685.2	351.6	94.7	5.3	0.0	1740.8
1996	33.7	213.6	683.2	173.9	52.5	2.9	0.0	1159.8
1997	25.2	260.5	433.1	274.1	76.3	9.8	1.2	1080.3
1998	76.9	185.3	552.4	161.2	108.5	23.9	0.8	1105.0
1999	193.9	301.4	462.1	113.9	57.7	16.9	0.4	1146.3
2000	77.8	114.5	351.5	140.2	39.8	14.0	0.0	737.7

Table 5.1 Current conditions for VPA-generated indices and juvenile abundance indices compared to long-term median and interquartile range. Values for 2000 that fall within the interquartile range should not be considered different from the long-term median (50th percentile).

Population-Based (VPA) Variables (Reduction fishery data only)

Variable	n	2000	25th	50th	75th
Full F (2+)	46	1.1	1.1	1.4	1.7
R_1 (billions)	46	0.8	1.9	3.0	4.5
SSB (1000 t)	46	33.2	20.9	39.9	62.9
SPR (%)	46	8.6	3.1	5.5	8.2

Population-Based (VPA) Variables (Reduction & Bait fishery data)

Variable	n	2000	25th	50th	75th
Full F (2+)	46	0.6	1.0	1.3	1.6
R_1 (billions)	46	1.2	2.1	3.2	4.7
SSB (1000 t)	46	90.1	28.0	54.5	88.7
SPR (%)	46	21.5	3.6	6.5	11.2

Standardized Juvenile Abundance Indices for:

Variable	n	2000	25th	50th	75th
SEAMAP (age-1)	12	-0.21	-0.68	-0.33	0.39
SEAMAP (age-2)	12	-0.13	-0.78	-0.29	0.52
NC Combined	29	-1.10	-0.77	-0.04	0.42
VA Seine	27	-0.77	-0.64	-0.45	0.28
MD Seine	42	-0.92	-0.90	-0.34	0.85
CT Combined	17	0.46	-0.56	-0.43	0.25
RI Combined	22	4.41	-0.27	-0.27	-0.23
Coastwide	42	-0.78	-0.81	-0.17	0.43

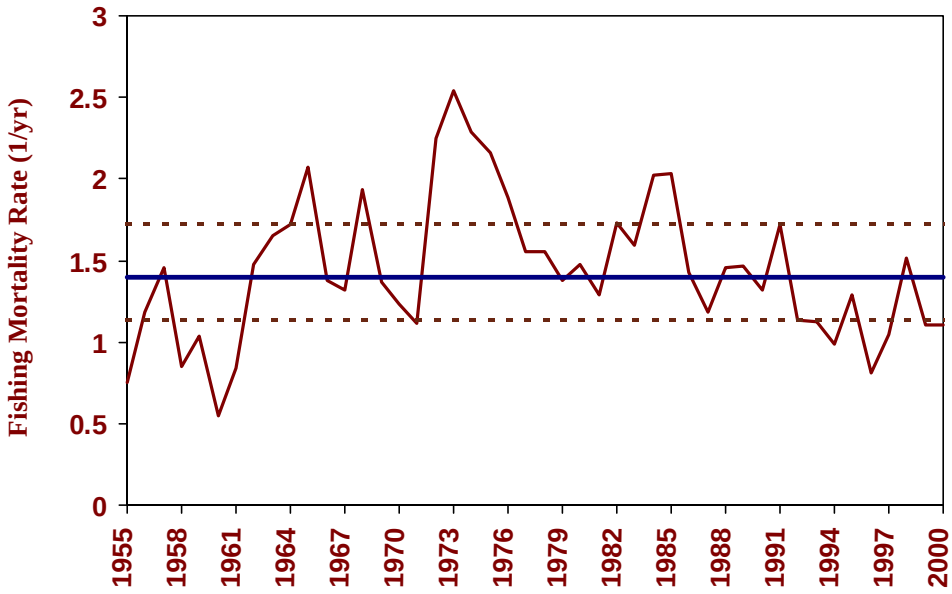

Figure 2.5. **Annual estimates of fishing mortality rates, F, averaged over fully recruited ages (2+) and weighted by population numbers at age with median and interquartile range.**

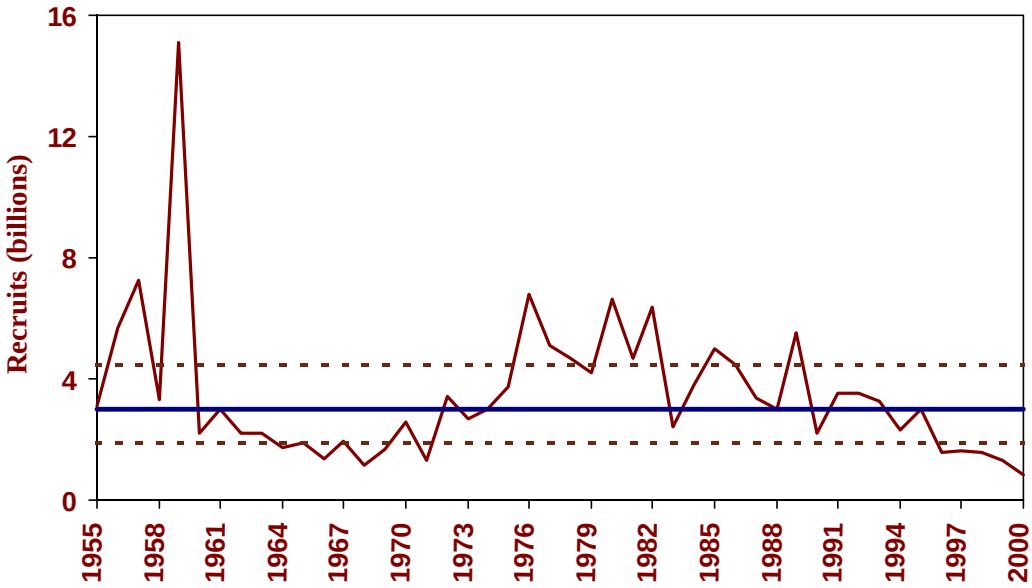

Figure 2.7. Estimates of recruits to age-1 Atlantic menhaden with median and interquartile range.

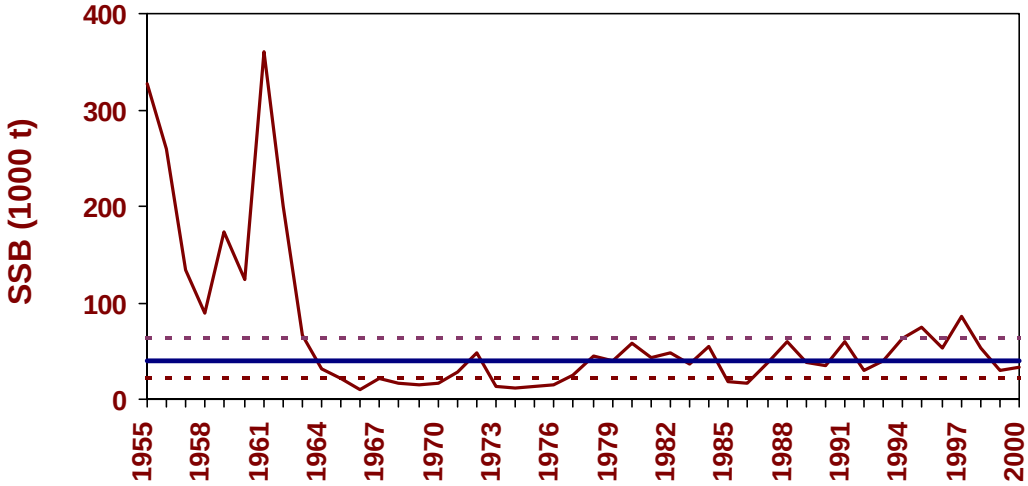

Figure 2.8. **Estimates of spawning stock biomass (SSB, age 3-8) of Atlantic menhaden with median and interquartile range.**

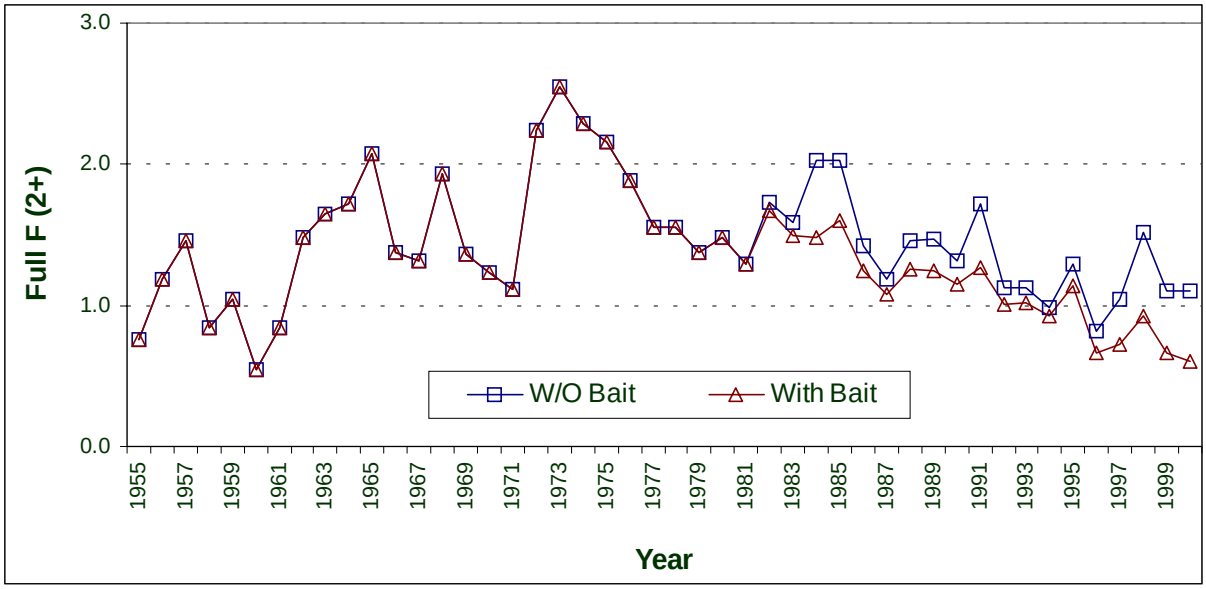

Figure 3.1. **Annual estimates of fishing mortality rates (weighted mean over ages 2 and older) from Murphy VPA using Atlantic menhaden catch-at-age with and without bait landings.**

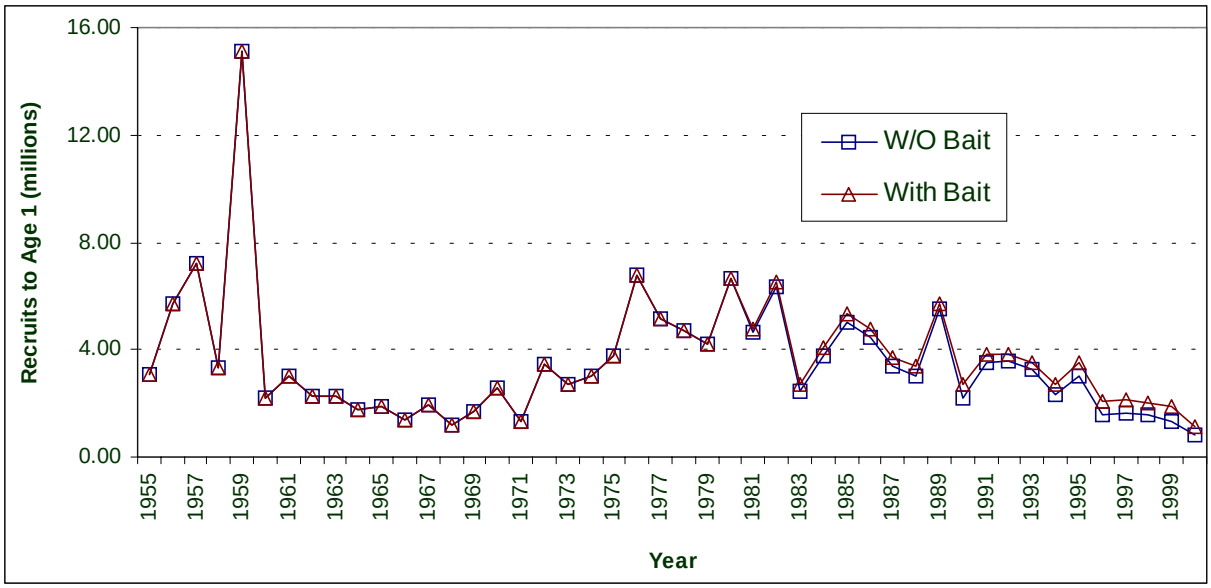

Figure 3.2. Annual estimates of recruits to age 1 from Murphy VPA using Atlantic menhaden catch-at-age with and without bait landings.

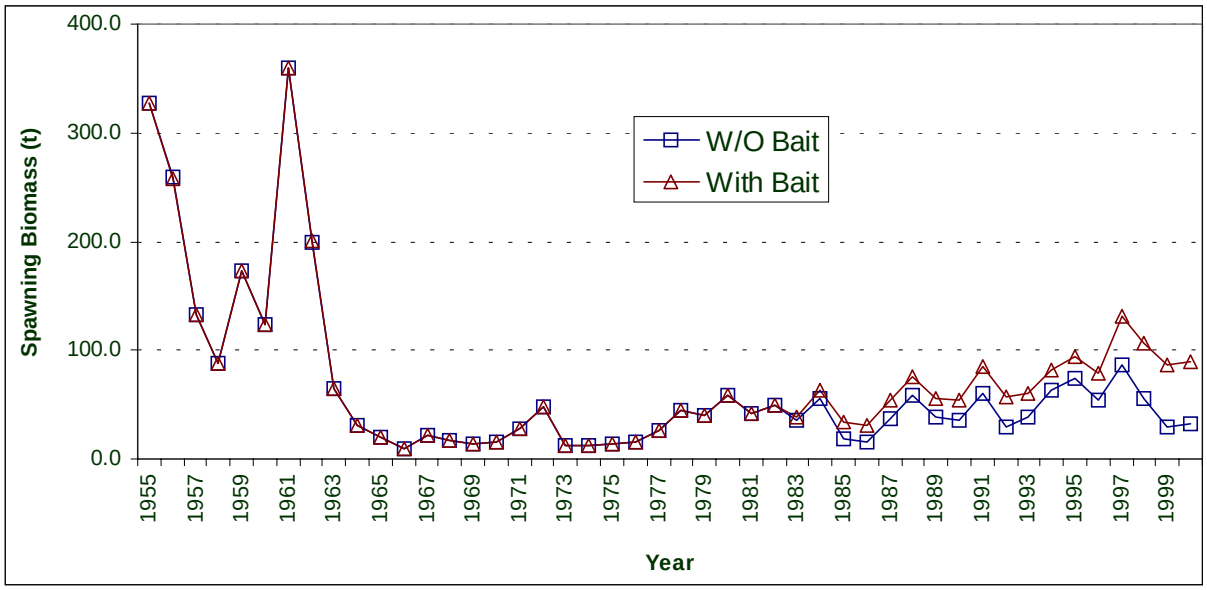

Figure 3.3. Annual estimates of spawning stock biomass (ages 3-8) from Murphy VPA using Atlantic menhaden catch-at-age with and without bait landings.

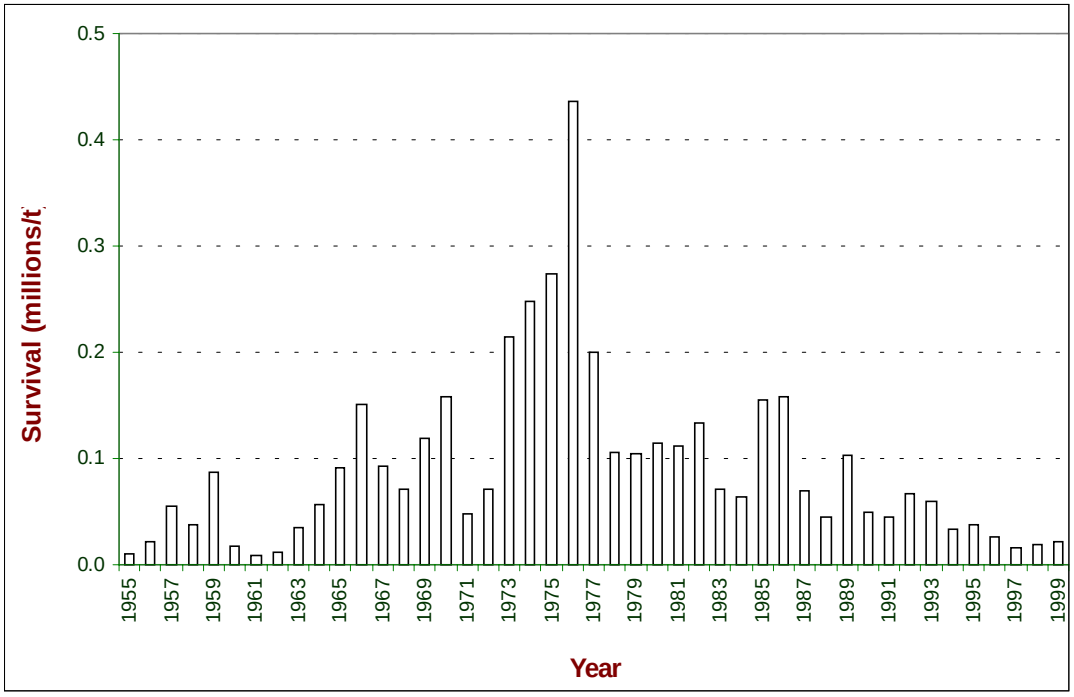

Figure 4.2. Observed survival (millions of recruits to age 1 per metric ton spawning biomass) of Atlantic menhaden.