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U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

The closed corridor management option, proposed by the Atlantic Menhaden Advisory Committee (AMAC) to the Atlantic Menhaden Implementation Subcommittee (AMIS), would prohibit purse-seine fishing in an area extending from the beach to one mile offshore between Cape Henry, Virginia, and Cape Fear, North Carolina, November through January. The intent of the proposal was to protect young Atlantic menhaden ("peanuts"); 65% of all age-0 fish landed were caught in this proposed closed corridor from 1978-1982.

Biological effects of implementing the closed corridor policy were studied by hypothesizing three ways in which fishing effort would be affected by the regulation, and then comparing each outcome with the anticipated landings without the regulation. The three hypotheses included: (I) No redeployment of fishing effort from the closed corridor, (II) complete redeployment of fishing effort from the closed corridor to outside waters, and (III) complete redeployment of fishing effort from the closed corridor to inside and outside waters. Hypothesis III was deemed the most realistic, and it exhibited the least gains in yield-per-recruit, ranging from 0.3 to 3.6% for the entire fishery. There is no biological advantage to the closed corridor management option since the gain is smaller than the predicted gain of 5.7% from a shortened menhaden season (Option 7) which is the coastwide management measure recommended by the Atlantic State Marine Fisheries Commission (ASMFC) and Atlantic Menhaden Management Board (AMMB).

INTRODUCTION

The closed corridor (or closed area) was one of several management options proposed by the Atlantic Menhaden Advisory Committee (AMAC) to the Atlantic Menhaden Implementation Subcommittee (AMIS) in a report dated May 1982. This option would prohibit purse-seine fishing in an area extending from the beach to one mile offshore between Cape Henry, Virginia, and Cape Fear, North Carolina, during the period November through January. The intent of the proposal was to protect a significant fraction of young Atlantic menhaden ("peanuts") thought to occur predominantly within the 0 to 1 mile zone during the North Carolina fall fishery. Inside waters (rivers and sounds) were not addressed in this option.

In late 1983 Dr. Vito J. Blomo, East Carolina University, requested access to part of the data collected by the Menhaden Program of the National Marine Fisheries Service (Beaufort Laboratory) for use in research funded by North Carolina Sea Grant (Blomo and Crouse 1985). The requested data included port sampling data and captain's daily fishing reports during the fall fishery for 1978 through 1982 from North Carolina plants (Beaufort Fisheries, Beaufort; Sea and Sound Processing Company, Beaufort; and Standard Products of North Carolina, Beaufort and Southport). This information was made available to Blomo after release of confidential data by affected companies (memo dated December 19, 1983 and letter dated January 24, 1984).

During 1984 Blomo requested further assistance from Beaufort Laboratory staff in performing appropriate yield-per-recruit analyses on these data. The yield-per-recruit analysis was performed at the Beaufort Laboratory and the results were provided to Blomo for use in his analyses and report to North Carolina Sea Grant. The yield-per-recruit analysis requires area- and age-specific information on fishing mortality and growth.

This report contains a description of geographic and seasonal fishing areas, description of the data available for this study, description of a series of computations which split out coastwide, age-specific instantaneous fishing mortality rates by fishing areas, and combine mortality and growth rates across fishing years. Results of the latter computations are used for MAREA program computer runs (Epperly et al. 1979) to obtain estimates of yield-per-recruit by fishing area and for the entire fishery. In addition to analyses that assume the closed corridor option is not implemented, three hypothetical scenarios are investigated. They reflect three ways that fishing effort may be redeployed by the fishing industry: (I) no redeployment of fishing effort, (II) redeployment of fishing effort outside the 1 mile limit of the closed corridor, and (III) redeployment of fishing effort to inside waters (rivers and sounds) and outside the 1 mile limit. Assumptions and results of the yield-per-recruit analysis are summarized and discussed.

GEOGRAPHIC AND SEASONAL FISHING AREAS

June and Reintjes (1959) divided the Atlantic coast into four geographic fishing areas and one temporal fishing area (Fig. 1). With only a change in the boundary line between the South Atlantic and Chesapeake Bay areas (Nicholson 1975), these divisions have continued to be useful.

North Atlantic Area: Waters along the southern coast of Long Island, east of a line due south of Moriches Inlet, New York, and waters northward.

Middle Atlantic Area: Waters west of a line due south of Moriches Inlet, New York (latitude 40°46'N and longitude 72°44'W) on the southern coast of Long Island, southward to Great Machipongo Inlet, Virginia.

Chesapeake Bay Area: Chesapeake Bay proper and coastal waters south of Great Machipongo Inlet, Virginia (latitude 37°22'N and longitude 75°43'W) to latitude 36°20'N on the North Carolina coast.

South Atlantic Area: Coastal waters of North Carolina south of latitude 36°20'N to Cape Canaveral, Florida.

North Carolina Fall fishery: A temporal fishing area consisting of waters from Cape Hatteras, North Carolina, south to the southern border of North Carolina, beginning between the last week of October and the second week of November, depending on the arrival of migratory menhaden from northern waters, and extending to the end of February of the next calender year (fishing usually stops by mid January). For purposes of standardized data summary, the week of each season which ends between November 8 and November 14 is taken to be the first week of the fall fishery and coincides with the proposed start of the closed corridor option.

For this report the North and Middle Atlantic fishing areas are combined to form Area A, the Chesapeake Bay fishing area is referred to as Area B, and the South Atlantic fishing area is referred to as Area C. The North Carolina fall fishery is split into three areas: (D) Inside waters including bays and sounds, (E) proposed closed corridor (0-1 mile offshore), and (F) outside waters located more than 1 mile offshore.

The fishing year is divided into four seasons or quarters:

Quarters	Beginning Week Ending Date	Ending Week Ending Date
1	> 3/1	< 5/24
2	> 5/23	< 8/16
3	> 8/15	< 11/8
4	> 11/7	< 14/29

where month 14 is February in the following calendar year. These quarters (each approximately 12 weeks except for the fourth quarter) are designed so that the start of the fourth quarter and the North Carolina fall fishery coincide. All catch and growth information in the analysis use this

definition for quarters. Estimates of age-specific instantaneous fishing mortality rates obtained from Dean W. Ahrenholz (Beaufort Laboratory) employed a slightly different definition for quarters (see Table 2 in Ahrenholz 1984).

DATA AVAILABILITY

Three types of data are used in the following analysis: (1) plant records, (2) biostatistical samples, and (3) captain's daily fishing reports. Plant records, provided by industry to NMFS (Beaufort Laboratory) for all menhaden purse-seine landings, contain information on the volume of Atlantic menhaden landed by each vessel at each port for every fishing trip. The biostatistical samples (10 fish per sample) are collected by NMFS personnel from the final set of a purse-seine fishing trip. Each fish is measured for length and weight and a scale sample is collected to determine age. The captain's daily fishing reports (CDFR) contain detailed information on the location (e.g., distance from shore) and size of each purse-seine set. Plant records and biostatistical samples are available since 1955, CDFRs are available since 1978. Because the 1983 North Carolina fall fishing season was still in progress when this study began, only data from 1978 through 1982 were used in the following analysis.

The intersection of the biostatistical data base, containing information on the age of the fish, and the CDFRs, containing information on set size and distance from shore, can be used to obtain estimates of the landings in numbers at age for inside waters, the proposed closed corridor (0-1 mile), and outside waters (>1 mile) during the North Carolina fall fishery. These estimated landings in numbers at age are the basis for combining or separating estimates of growth and fishing mortality rates across fishing years and/or areas. Note in Table 1 that no CDFRs are available from Beaufort

Fisheries Inc. for the period 1978-1982, and that biostatistical samples from Standard Products of NC Inc.-Southport are only available for the 1982 fishing year. An important assumption in the following analysis is that the matched data set (i.e., intersection of biostatistical and CDFR data sets) adequately describes the catch from Cape Henry, Virginia, to Cape Fear, North Carolina, during the North Carolina fall fishery. In particular, we assume that the lack of data from Beaufort Fisheries does not bias the results.

A distinction is needed between catches and landings, especially when referring to geographic locations. The location of catches refers to where the fish were caught (i.e., where the sets were made), while the location of landings refers to where the fish were offloaded (i.e., at reduction plants). In addition to the North Carolina plants (footnote to Table 1), Atlantic menhaden from the proposed closed corridor during 1978-1982 could have been landed at several other plants, including two plants in Reedville, Virginia, and one plant in Port Monmouth, New Jersey (which ceased operation after the 1981 fishing season). No landings were made at Port Monmouth, New Jersey, of fish caught between Cape Henry and Cape Fear during the fourth quarter, while about 10% of the landings at Reedville, Virginia, were caught between the capes during the fourth quarter. Over 99% of the North Carolina plant landings came from between the capes during the North Carolina fall fishery (fourth quarter). To simplify our analysis, it was assumed that reported catches equal landings and that we could restrict our analysis to North Carolina plants when estimating catches in numbers at age from inside, closed corridor and outside waters between the capes during the North Carolina fall fishery.

CATCH IN NUMBERS AT AGE BY AREA

The matched data set (intersection of the biostatistical and CDFR data sets for 1978-1982 during the North Carolina fall fishery) was entered on

a computer data file by Blomo at East Carolina University. At the request of Beaufort Laboratory, the following data summaries were performed:

(1) For each week in each year (weeks run from Monday through Friday), calculate the total captain's estimated catch in standard fish from each of the three areas (inside waters, closed corridor, and outside waters), and then calculate the proportion of catch from each of the three areas by week in each year. Note that one standard fish is equivalent to 303.9 g.

(2) For each week in each year, calculate the mean weight of an individual fish in each of the three areas (divide total weight of samples by number of individual fish in samples for each week in each year).

(3) For each week in each year, calculate the proportion of each age group present in each area for that week's samples.

The weekly proportion of captain's estimated catch among the three areas for the matched data set (see Item 1 above) was used to determine the landings from each of the areas based on total landings in biomass for the North Carolina fall fishery obtained from the plant record data set for all North Carolina plants. Since there were weeks with no data available from the matched data set, a method was developed to fill in for these weeks with missing data. Weeks were grouped by month (November through January) so that values for weeks in a month when data were available were used for weeks in the same month when data were unavailable. In instances when this approach could not be used, the cross-year (1978-1982) average for a particular week was used for that week and year when data were unavailable. Catch by week within year and by area were calculated and converted from standard fish to grams.

As with calculating weekly catches in grams, there were weeks for which the mean weight of an individual fish was unavailable (see Item 2 above). Again, weeks were grouped by month so that data for some weeks in a month were used for other weeks in the same month. Cross-year averages were used for weeks when necessary. The catches in numbers by week within year and for each area were obtained by dividing weekly catches in grams by corresponding weekly mean weights of individual fish in grams for each year and area.

The next step required estimates of catches in numbers of fish in each age group for each week within year and for each area (see Item 3 above). Missing values for certain weeks were obtained in the same manner as for calculating weekly catches and mean weight of individual fish. These proportions for each age group were used to obtain estimates of catches in numbers at age for each week within year and for each area. Summing catches in numbers at age over the weeks within each year and each area gave estimates of catch in numbers at age by year and area.

Catches in numbers at age are estimated from the plant record and biostatistical data sets by week for each of the five NMFS areas previously defined (North Atlantic, Middle Atlantic, Chesapeake Bay, South Atlantic, and North Carolina fall fishery) at the completion of each fishing year. Summing catches in numbers at age over the weeks in each quarter and combining them for the North and Middle Atlantic fishing areas, the catches in numbers at age (by quarters) for four study areas (i.e., A, B, C, and D-F combined) are estimated. Table 2 shows the annual coastwide catches in numbers at age by quarter) for Areas A-F combined.

The catches in numbers at age by year for the North Carolina fall fishery obtained from the complete plant record and biostatistical data sets can be divided into three areas: Area D (inside waters), Area E (closed corridor), and Area F (outside waters). This division is proportional to the contribution observed in the matched data set from these three areas. The percent of landings by area for each age (in quarters) is obtained by summing catches in numbers at age over the five-year study period (Table 3). To more easily assess the contribution from each fishing area (A-F) of catches in numbers at age, the catches in numbers at age by area were summed over quarters and the percent contribution of each area to the total catches in numbers at age for each age group was calculated (Table 4). Areas D and E were the sources of the

greatest numbers of age-0 Atlantic menhaden landed, contributing 27 and 65%, respectively.

FISHING MORTALITY BY AGE AND AREA

Estimates of age-specific instantaneous fishing mortality rates were obtained from virtual population analysis (results provided by Dean W. Ahrenholz, Beaufort Laboratory, personal communication). This analysis used an estimate of 0.45/year for instantaneous natural mortality rate for all adult age groups. Estimates for the fishing years 1978-1982 are presented in Table 5. Since virtual population analysis is conducted on cohorts, or all fish spawned during the same spawning year, estimates of the instantaneous fishing mortality rates were not available for age-0 fish in 1980-1982, age-1 fish in 1981 and 1982, and age-2 fish in 1982. Mean instantaneous fishing mortality rates by age (in quarters) were calculated using catches in numbers at age by year as weighting factors; i.e.,

$$\bar{x} = \Sigma f_i x_i / \Sigma f_i, \qquad (1)$$

where x_i are the annual instantaneous fishing mortality rates for a given age group (in quarters), f_i are the corresponding weighting factors (catches in numbers at age in quarters), i represents the individual fishing years (1978-1982) being summed over, and $\bar{x}$ is the mean instantaneous fishing mortality rate for the given age group (in quarters).

Minimum and maximum estimates of instantaneous fishing mortality rates by age were obtained for each age in quarters by selecting the smallest and largest annual values of the instantaneous fishing mortality rate, respectively. These three sets of age-specific mortality rate estimates were then divided proportionally according to the catches in numbers at age (in quarters) into the six study areas (Table 6).

The yield-per-recruit analysis that follows depends on these sets of age-specific mortality estimates. Two sets of yield-per-recruit analyses are made directly from these estimates: (1) an initial computer run assuming no implementation of the closed corridor management option (used as the basis for subsequent comparisons), and (2) an additional computer run assuming the closed corridor option is implemented and no shifting of fishing effort from Area E to any other fishing area (referred to as Hypothesis I).

Two other hypothetical scenarios are investigated in this study. Hypothesis II suggests that all fishing effort from Area E (closed corridor) is redirected to Area F (outside waters), while Hypothesis III suggests that all fishing effort from Area E is proportioanlly divided between Areas D (inside waters) and F. To investigate these hypotheses, a constant relationship between fishing effort and catch per unit of fishing effort within any given fishing year (i.e., 1978-1982) had to be assumed. I believe this assumption is approximately true within any given geographic area and season, but it becomes less tenable when comparing catches across major geographic areas or seasons.

Adjustment of the estimates of age- and area-specific instantaneous fishing mortality rates used the matched data set (intersection of the biostatistical and CDFR data sets) to obtain estimates for Areas D-F of fishing effort (number of purse-seine sets) and catch per unit of fishing effort (catch in numbers of fish divided by the number of sets). For Hypothesis II multiplying the catch per unit of fishing effort for each year (1978-1982) from Area F by the fishing effort for each year from Area E resulted in an annual estimate of the extra catch in numbers from Area F due to shifting fishing effort from Area E to Area F. The ratio of these extra catches at age from Area F to the total catches at age from Area E provides a means of calculating the instantaneous fishing mortality rate from Area E that can be applied to Area F. Adding these

to the age-specific mortality rates from Area F, a new set of age-specific instantaneous fishing mortality rates is obtained for Area F (Table 7, Hypothesis II).

Similarly, these calculations were repeated for Hypothesis III, except that the fishing effort for Area E was proportionally divided between Areas D and F according to the proportion of the catch in numbers at age between the two areas (Table 7, Hypothesis III). For analysis of Hypotheses II and III, it is assumed that there are sufficient fish available in Areas D and/or F during the fourth quarter to be caught at the same level of catch per unit of fishing effort as in the historical data (e.g., the matched data set for 1978-1982).

GROWTH IN WEIGHT BY AREA

In addition to estimates of age- and area-specific instantaneous fishing mortality rates and an estimate of instantaneous natural mortality rate (0.45/year), the yield-per-recruit analysis requires estimates of the growth in weight of individual Atlantic menhaden from each study area and for the entire fishery. The entire biostatistical data base for fishing years 1978-1982 was used to obtain estimates of weight at age for Areas A-C. With annual estimates of weight at age for NMFS fishing areas (specifically North Atlantic, Middle Atlantic, Chesapeake Bay, and South Atlantic), estimates of weight at age were averaged across years using Eq. (1) with catch in number at age (in quarters) for each area and year as the weighting factors (f_i). The estimates of weight for the North and Middle Atlantic areas were then averaged, again using Eq. (1). Comparable estimates of weight at age for Areas D-F were obtained from the matched data set. Mean weights at age (in quarters) were also computed for the entire fishery using catch in numbers at age for each area as the weighting factors in Eq. (1).

Given these estimates of weight at age for Areas A-F and the entire fishery, estimates of the parameters of the von Bertalanffy growth equation were made (Table 8):

$$W_t = W_\infty (1 - \exp(-k(t-t_0))^3. \qquad (2)$$

Weight at age (in quarters) were then recomputed from Eq. (2) for each area and inserted into the yield-per-recruit algorithm (MAREA). Growth of individual Atlantic menhaden in Areas D-F are compared in Fig. 2.

RESULTS AND DISCUSSION

Twelve sets of MAREA computer runs (Epperly et al. 1979) were made to investigate the biological consequences of instituting a closed corridor from 0-1 mile offshore between Cape Henry, Virginia, and Cape Fear, North Carolina, during the fourth quarter of the fishing year (i.e., closure of Area E to purse-seine fishing). In addition to the base run which assumed no implementation of the closed corridor management option, three hypothetical scenarios (Hypotheses I-III) based on the redeployment of fishing effort from Area E were considered. These scenarios included no redeployment of fishing effort from Area E (Hypothesis I), complete redeployment of fishing effort from Area E to Area F (outside waters) (Hypothesis II), and complete redeployment of fishing effort from Area E proportionally to Areas D (inside waters) and F (Hypothesis III). Each set of base run and runs for the three hypothetical scenarios were repeated for sets of minimum, mean, and maximum estimates of instantaneous fishing mortality rates. The results of these are summarized in Table 9.

Several of the major assumptions made in this analysis are concerned with data limitations: the matched data set is restricted to the 1978-1982 fishing years, no matches are available for Beaufort Fisheries for any of these five years, and no matches are available for Standard Products of North

Carolina, Southport Plant, for the 1978-1981 fishing years, nor for Sea and Sound Processing Company for the 1982 fishing year. These data limitations force the assumption that the missing information is not significantly different from that available, from Standard Products of North Carolina, Beaufort Plant, and Sea and Sound Processing Company. It was also necessary to assume that all North Carolina fall fishery landings come from between the capes during the fourth quarter, and that all other landings during the fourth quarter do not. The former part of this assumption appears to be well-substantiated (99% of the biostatistical samples for North Carolina fall fishery plants were from between the capes in the fourth quarter for 1978-1982), but the latter part of this assumption is less well-substantiated (10% of Reedville landings were from between the capes during the fourth quarter for 1978-1982). Another major assumption concerns the availability of fish for the increased catches in Areas D and/or F under Hypotheses II and III. This assumption requires that increased fishing effort for these areas will result in greater catches as predicted by multiplying the annual catch per unit effort for Area D or F by the increase in fishing effort redeployed from Area E.

Largest gains in yield-per-recruit are from no redeployment of fishing effort from the closed corridor (Hypothesis I) and the least gains are from redeployment of fishing effort to inside and outside waters (Hypothesis III) (Table 9). Area B (Chesapeake Bay Area) makes the largest contribution to yield-per-recruit (without regulation) and the next largest is from Area C (South Atlantic Area, not including the North Carolina fall fishery). Some of the gains that would otherwise accrue are lost with redirection of effort to outside waters (Hypothesis II) or to both inside and outside waters (Hypothesis III) due to the additional catches from the redirected fishing effort from the closed corridor (Area E). Since inside waters (Area D) contribute the next

largest catch in numbers of age-0 fish after Area E (Table 4), redirecting effort only to outside waters Hypothesis II will result in higher yield-per-recruit than redirecting some of that effort to Area D (Hypothesis III). Further, the higher catch per unit of fishing effort for Area D compared to Area F (for the matched data set) also contributes to greater gains in yield-per-recruit from Hypothesis II than from Hypothesis III.

Redeployment of fishing effort to inside and outside waters (Hypothesis III) would appear a priori to provide the most likely response of the menhaden purse-seine fleet to implementation of the closed corridor option. The gain in yield-per-recruit under this hypothesis for the entire fishery ranges from 0.3 to 3.6%. This gain is small compared to the expected gain of 5.7% from a shortened season (Option 7) (Epperly 1982) which was passed by the Atlantic Menhaden Management Board (AMMB) and Atlantic States Marine Fisheries Commission (ASMFC) and implemented by several Atlantic coastal states (New Jersey, New York, Connecticut, Rhode Island, and New Hamphsire). Also for Hypothesis III, gains in relative yield-per-recruit for Areas A-C ranged from 1.2 to 5.1%, while relative changes in yield-per-recruit for Areas D-F combined (corresponds to the North Carolina Fall fishery) ranged from a loss of about 16% for minimum and mean sets of F's to a gain of 2.5% for the maximum set of F's. Thus, there is no biological basis for recommending the closed corridor option over Option 7.

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Table 1. Summary of data available from Atlantic menhaden, North Carolina Fall fishery for 1978-1982 fishing seasons.

Data/Plant[a]	1978	1979	1980	1981	1982	Total
Biostatistical Samples[b]	66	91	113	75	64	409
1	26	37	68	39	21	191
2	7	15	16	13	9	60
3	33	39	29	23	26	150
4	0	0	0	0	8	8
CDFRs[c]	496	442	350	404	345	2,307
1	0	0	0	0	0	0
2	65	87	80	37	0	269
3	371	355	256	273	283	1,538
4	60	0	14	94	62	230
Matched Samples[d]	28	49	38	20	32	167
1	0	0	0	0	0	0
2	4	11	12	5	0	32
3	24	38	26	15	25	128
4	0	0	0	0	7	7
Inside Waters	9	11	21	5	2	48
Closed Corridor	19	32	11	14	21	97
Outside Waters	0	6	6	1	9	22

[a] Reduction plants with their numeric designations are as follows: Beaufort Fisheries Inc. (1); Sea and Sound Processing Co. (2); and Standard Products of NC Inc., Beaufort (3); and Southport (4).

[b] The number of final sets of a fishing trip by a vessel sampled during the North Carolina Fall fishery and caught between Cape Henry, Virginia, and Cape Fear, North Carolina.

[c] The number of sets made during the North Carolina Fall fishery between Cape Henry, Virginia, and Cape Fear, North Carolina, and included in Captain's Daily Fishing Reports (CDFRs).

[d] The number of sets for which both biostatistical samples (footnote b) and CDFRs (footnote c) are jointly available.

Table 2. Landings (numbers in millions) of Atlantic menhaden at age (by quarter) coastwide for fishing years 1978-1982.

Age[a]	Fishing Year 1978	1979	1980	1981	1982
0.50	0.3	13.6	0.4	88.6	12.4
0.75	456.7	1,421.6	94.4	1,126.1	101.7
1.00	18.4	10.3	126.2	6.9	20.6
1.25	178.1	133.0	284.3	179.3	309.4
1.50	297.4	367.2	691.5	259.5	450.4
1.75	167.0	100.3	343.3	272.7	139.1
2.00	94.8	87.4	28.0	98.4	130.3
2.25	1,014.8	1,011.9	896.9	1,125.2	1,118.6
2.50	507.6	433.0	488.5	434.0	431.6
2.75	51.5	61.7	48.3	144.4	56.4
3.00	13.2	1.6	5.1	31.4	61.1
3.25	156.8	63.3	133.3	143.4	210.7
3.50	74.6	45.2	64.3	35.1	84.4
3.75	12.8	16.1	20.7	11.2	15.5
4.00	0.3	0.0	0.0	0.3	0.0
4.25	17.3	7.9	31.3	38.4	10.1
4.50	7.3	9.1	24.7	8.7	2.3
4.75	6.9	4.4	13.2	0.0	3.1
5.00	0.0	0.0	0.0	0.0	0.0
5.25	2.2	0.9	5.8	13.1	3.5
5.50	0.7	0.4	5.4	2.2	1.0
5.75	0.6	0.0	3.2	0.0	0.9
6.00	0.0	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.6	0.9	0.8
6.50	0.0	0.2	0.2	0.3	0.0
6.75	0.0	0.0	0.7	0.0	0.0

a In years; definition of quarters given in Geographic and Seasonal Fishing Areas section.

Table 3. Percent of landings of Atlantic menhaden in numbers at age (by quarter) for the six study areas for the years 1978-1982.

Age[b]	Study Areas[a]					
	A	B	C	D	E	F
0.50	0.0	53.3	46.7	0.0	0.0	0.0
0.75	0.0	1.0	0.0	27.7	67.2	4.2
1.00	0.0	0.0	100.0	0.0	0.0	0.0
1.25	0.4	46.3	53.3	0.0	0.0	0.0
1.50	0.3	84.2	15.5	0.0	0.0	0.0
1.75	0.0	14.5	0.0	20.9	55.0	9.6
2.00	1.3	29.9	68.8	0.0	0.0	0.0
2.25	4.9	69.8	25.3	0.0	0.0	0.0
2.50	4.7	73.5	21.8	0.0	0.0	0.0
2.75	0.1	6.4	0.1	20.7	62.6	10.1
3.00	4.1	23.9	72.0	0.0	0.0	0.0
3.25	41.9	30.2	27.9	0.0	0.0	0.0
3.50	44.9	32.5	22.6	0.0	0.0	0.0
3.75	19.5	3.3	0.0	14.5	53.6	9.0
4.00	56.9	0.0	43.1	0.0	0.0	0.0
4.25	95.8	3.2	1.0	0.0	0.0	0.0
4.50	96.6	2.7	0.7	0.0	0.0	0.0
4.75	24.0	0.0	0.0	25.4	40.9	9.7
5.00	0.0	0.0	0.0	0.0	0.0	0.0
5.25	100.0	0.0	0.0	0.0	0.0	0.0
5.50	100.0	0.0	0.0	0.0	0.0	0.0
5.75	14.1	0.0	0.0	26.4	58.0	1.6
6.00	0.0	0.0	0.0	0.0	0.0	0.0
6.25	97.0	0.0	3.0	0.0	0.0	0.0
6.50	100.0	0.0	0.0	0.0	0.0	0.0
6.75	31.9	0.0	0.0	17.8	48.9	1.5

a Area definitions are as follows: (A) North and Middle Atlantic areas, (B) Chesapeake Bay area, (C) South Atlantic area, (D) North Carolina fall fishery (inside waters), (E) North Carolina fall fishery (closed corridor, 0-1 mile offshore), and (F) North Carolina fall fishery (outside waters, >1 mile offshore).

b In years; definition of quarters given in Geographic and Seasonal Fishing Areas section.

Table 4. Percent of landings of Atlantic menhaden in numbers at age for the six study areas for the years 1978-1982.

Age	Study Areas[a]					
	A	B	C	D	E	F
0	0.0	2.8	1.6	26.7	64.9	4.0
1	0.3	55.6	23.8	5.0	13.1	2.3
2	4.7	61.9	29.4	0.9	2.7	0.4
3	36.1	25.6	33.2	1.0	3.5	0.6
4	84.7	2.3	0.9	4.0	6.5	1.5
5	90.0	0.0	0.0	3.1	6.8	0.2
6	84.4	0.0	2.1	3.5	9.7	0.3

a Area definitions given in footnote (a) to Table 3.

Table 5. Annual and mean instantaneous fishing mortality rates of Atlantic menhaden from virtual population analysis[a] for 1978-1982 fishing years.

Age	Fishing Year 1978	1979	1980	1981	1982	Mean[b]
0.50	0.0233	0.0017	c	c	c	0.0021
0.75	0.0676	0.1775	c	c	c	0.1508
1.00	0.0063	0.0038	0.0197	c	c	0.0171
1.25	0.0636	0.0389	0.0630	c	c	0.0578
1.50	0.0826	0.1274	0.1634	c	c	0.1359
1.75	0.0414	0.0294	0.0697	c	c	0.0553
2.00	0.0533	0.0618	0.0395	0.0478	c	0.0527
2.25	0.8690	0.7487	0.7780	0.6102	c	0.7469
2.50	0.4784	0.5022	0.5345	0.4118	c	0.4831
2.75	0.1042	0.0996	0.1067	0.0713	c	0.0881
3.00	0.0618	0.0169	0.0359	0.1396	0.1308	0.1192
3.25	0.8080	0.2626	0.6050	0.8040	0.6227	0.6650
3.50	0.4021	0.2303	0.3560	0.4958	0.2766	0.3427
3.75	0.1747	0.0523	0.1851	0.0	0.0969	0.1102
4.00	0.0087	0.0	0.0017	0.0255	0.0	0.0163
4.25	0.6078	0.2678	0.3966	0.9843	0.0	0.5987
4.50	0.3383	0.2135	0.4051	0.2974	0.0	0.3268
4.75	0.7835	0.1024	0.2840	0.0	0.0	0.3493
5.00	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.8104	0.3236	0.4646	0.8379	0.0	0.4587
5.50	0.5006	0.0175	0.6624	0.1567	0.0	0.4391
5.75	0.9862	0.0	0.7625	0.0	0.0	0.5252
6.00	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.3194	0.8916	0.0	0.3533
6.50	0.0	1.5405	0.3450	0.4271	0.0	0.6956
6.75	0.0	0.0	0.7689	0.0	0.0	0.7689

[a] Results of virtual population analysis provided by Dr. Dean Ahrenholz, Beaufort Laboratory.

[b] Mean instantaneous fishing mortality rates calculated by weighting the annual instantaneous fishing mortality rate by catch in numbers at age for each fishing year.

[c] No estimates of annual, age-specific instantaneous fishing mortality rate available.

Table 6. Minimum, mean, and maximum estimates of age- and area-specific instantaneous fishing mortality rates of Atlantic menhaden for the 1978-1982 fishing years.

Age	Study Areas[a]					
	A	B	C	D	E	F
	Minimum Fishing Mortality					
0.50	0.0	0.0009	0.0008	0.0	0.0	0.0
0.75	0.0	0.0007	0.0	0.0187	0.0454	0.0028
1.00	0.0	0.0	0.0038	0.0	0.0	0.0
1.25	0.0002	0.0180	0.0207	0.0	0.0	0.0
1.50	0.0002	0.0696	0.0128	0.0	0.0	0.0
1.75	0.0	0.0043	0.0	0.0061	0.0162	0.0028
2.00	0.0005	0.0118	0.0272	0.0	0.0	0.0
2.25	0.0299	0.4257	0.1546	0.0	0.0	0.0
2.50	0.0194	0.3027	0.0897	0.0	0.0	0.0
2.75	0.0001	0.0046	0.0	0.0148	0.0446	0.0072
3.00	0.0007	0.0040	0.0122	0.0	0.0	0.0
3.25	0.1100	0.0792	0.0734	0.0	0.0	0.0
3.50	0.1034	0.0748	0.0521	0.0	0.0	0.0
3.75	0.0	0.0	0.0	0.0	0.0	0.0
4.00	0.0	0.0	0.0	0.0	0.0	0.0
4.25	0.0	0.0	0.0	0.0	0.0	0.0
4.50	0.0	0.0	0.0	0.0	0.0	0.0
4.75	0.0	0.0	0.0	0.0	0.0	0.0
5.00	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.0	0.0	0.0	0.0	0.0	0.0
5.50	0.0	0.0	0.0	0.0	0.0	0.0
5.75	0.0	0.0	0.0	0.0	0.0	0.0
6.00	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.0	0.0	0.0	0.0	0.0	0.0
6.50	0.0	0.0	0.0	0.0	0.0	0.0
6.75	0.0	0.0	0.0	0.0	0.0	0.0

Table 6 (cont.).

Age	Study Areas[a]					
	A	B	C	D	E	F
	Mean Fishing Mortality					
0.50	0.0	0.0011	0.0010	0.0	0.0	0.0
0.75	0.0	0.0015	0.0	0.0418	0.1013	0.0063
1.00	0.0	0.0	0.0171	0.0	0.0	0.0
1.25	0.0002	0.0268	0.0308	0.0	0.0	0.0
1.50	0.0004	0.1144	0.0211	0.0	0.0	0.0
1.75	0.0	0.0080	0.0	0.0116	0.0304	0.0053
2.00	0.0007	0.0157	0.0363	0.0	0.0	0.0
2.25	0.0366	0.5211	0.1892	0.0	0.0	0.0
2.50	0.0227	0.3551	0.1053	0.0	0.0	0.0
2.75	0.0001	0.0056	0.0001	0.0182	0.0552	0.0089
3.00	0.0049	0.0284	0.0859	0.0	0.0	0.0
3.25	0.2786	0.2005	0.1859	0.0	0.0	0.0
3.50	0.1539	0.1112	0.0776	0.0	0.0	0.0
3.75	0.0215	0.0036	0.0	0.0160	0.0591	0.0099
4.00	0.0093	0.0	0.0070	0.0	0.0	0.0
4.25	0.5736	0.0189	0.0062	0.0	0.0	0.0
4.50	0.3157	0.0089	0.0022	0.0	0.0	0.0
4.75	0.0838	0.0	0.0	0.0887	0.1429	0.0339
5.00	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.4587	0.0	0.0	0.0	0.0	0.0
5.50	0.4391	0.0	0.0	0.0	0.0	0.0
5.76	0.0741	0.0	0.0	0.1387	0.3046	0.0084
6.00	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.3427	0.0	0.0106	0.0	0.0	0.0
6.50	0.6956	0.0	0.0	0.0	0.0	0.0
6.75	0.2453	0.0	0.0	0.1369	0.3760	0.0115

Table 6 (cont.).

Age	Study Areas[a]					
	A	B	C	D	E	F
	Maximum Fishing Mortality					
0.50	0.0	0.0124	0.0109	0.0	0.0	0.0
0.75	0.0	0.0018	0.0	0.0492	0.1193	0.0075
1.00	0.0	0.0	0.0197	0.0	0.0	0.0
1.25	0.0003	0.0295	0.0338	0.0	0.0	0.0
1.50	0.0005	0.1375	0.0254	0.0	0.0	0.0
1.75	0.0	0.0101	0.0	0.0146	0.0383	0.0067
2.00	0.0008	0.0185	0.0425	0.0	0.0	0.0
2.25	0.0426	0.6062	0.2202	0.0	0.0	0.0
2.50	0.0251	0.3929	0.1165	0.0	0.0	0.0
2.75	0.0001	0.0068	0.0001	0.0221	0.0668	0.0108
3.00	0.0057	0.0333	0.1006	0.0	0.0	0.0
3.25	0.3386	0.2436	0.2258	0.0	0.0	0.0
3.50	0.2226	0.1609	0.1123	0.0	0.0	0.0
3.75	0.0361	0.0061	0.0	0.0268	0.0992	0.0167
4.00	0.0145	0.0	0.0110	0.0	0.0	0.0
4.25	0.9430	0.0311	0.0102	0.0	0.0	0.0
4.50	0.3913	0.0111	0.0027	0.0	0.0	0.0
4.75	0.1880	0.0	0.0	0.1990	0.3205	0.0760
5.00	0.0	0.0	0.0	0.0	0.0	0.0
5.25	0.8379	0.0	0.0	0.0	0.0	0.0
5.50	0.6624	0.0	0.0	0.0	0.0	0.0
5.75	0.1391	0.0	0.0	0.2604	0.5720	0.0158
6.00	0.0	0.0	0.0	0.0	0.0	0.0
6.25	0.8649	0.0	0.0267	0.0	0.0	0.0
6.50	1.5404	0.0	0.0	0.0	0.0	0.0
6.75	0.2453	0.0	0.0	0.1369	0.3760	0.0115

[a] Area definitions given in footnote (a) to Table 3.

Table 7. Adjusted age-specific instantaneous fishing mortality rates of Atlantic menhaden for inside (Area D) and outside (Area F) waters in the North Carolina fall fishery for two hypothetical scenarios (II and III) for redistributing fishing effort from the closed corridor area (E). Calculations made for three levels of instantaneous fishing mortality rates (minimum, mean, and maximum).

Age	Hypothesis II[a] Area F	Hypothesis III[a] Area D	Hypothesis III[a] Area F
	Minimum Fishing Mortality		
0.75	0.0143	0.0505	0.0078
1.75	0.0069	0.0174	0.0046
2.75	0.0185	0.0460	0.0121
3.75	0.0	0.0	0.0
4.75	0.0	0.0	0.0
5.75	0.0	0.0	0.0
6.75	0.0	0.0	0.0
	Mean Fishing Mortality		
0.75	0.0320	0.1127	0.0174
1.75	0.0130	0.0329	0.0086
2.75	0.0229	0.0568	0.0149
3.75	0.0249	0.0574	0.0164
4.75	0.0702	0.1887	0.0495
5.75	0.0858	0.3519	0.0417
6.75	0.1070	0.4000	0.0526
	Maximum Fishing Mortality		
0.75	0.0378	0.1327	0.0205
1.75	0.0164	0.0414	0.0109
2.75	0.0278	0.0688	0.0181
3.75	0.0419	0.0962	0.0275
4.75	0.1574	0.4233	0.1110
5.75	0.1611	0.6607	0.0783
6.75	0.1070	0.4000	0.0526

[a] All fishing effort is shifted from Area E (closed corridor) to Area F (outside waters) in Hypothesis II, while fishing effort is shifted proportionally from Area E to Areas D (inside waters) and F in Hypothesis III.

Table 8. Mean weight (g) at age for Atlantic menhaden by area and for the entire fishery.

Age	Areas[a] A	B	C	D	E	F	Entire Fishery
0.50		39.3	13.8				27.4
0.75		38.3		22.7	23.6	26.8	23.7
1.00			34.6				34.6
1.25	69.5	82.4	47.0				63.5
1.50	126.7	94.2	57.2				88.5
1.75		84.5		54.4	71.7	61.3	68.9
2.00	138.6	104.4	87.9				93.5
2.25	208.0	129.7	109.4				128.4
2.50	252.6	153.4	145.9				156.4
2.75	274.0	169.8		165.1	190.9	216.3	186.8
3.00	201.1	124.3	134.1				134.5
3.25	302.2	163.4	142.9				215.8
3.50	339.6	226.0	176.9				265.9
3.75	422.1	314.2		410.6	294.8	367.9	343.3
4.00	215.6		359.0				277.4
4.25	437.3	205.9	164.7				427.2
4.50	459.1	254.9	300.8				452.5
4.75	465.3			474.2	462.8	420.5	462.2
5.00							
5.25	489.3						489.3
5.50	501.5						501.5
5.75	479.0			542.0	542.9	410.0	532.1
6.00							
6.25	500.5		293.0				494.3
6.50	536.7						536.7
6.75	696.0						696.0
(7.25	549.0						549.0)
Von Bertalanffy Parameters							
n	21	15	14	6	6	6	25
W_∞	717.3	560.8	417.3	1,495.9	1,502.6	664.2	1,161.1
k	0.350	0.244	0.363	0.217	0.201	0.366	0.218
t_0	-0.54	-1.47	-0.43	-0.30	-0.51	-0.16	-0.68

[a] Area definitions are given in footnote (a) to Table 3).

Table 9. Percent change in yield per recruit by area, areas D-F combined, and for the entire Atlantic menhaden purse-seine fishery for three hypothetical scenarios based on the closed corridor management option compared to the present fishing regime for the 1978-1982 fishing seasons. Analysis performed for three levels of instantaneous fishing mortality rates (minimum, mean, and maximum).

Area[a]	Current (g)	Change (%) Hypotheses[b] I	II	III
		Minimum Fishing Mortality		
A	5.41	9.4	6.8	1.7
B	25.38	14.3	4.7	1.2
C	9.13	6.9	5.1	1.3
D	0.71	5.6	4.2	193.0
E	2.11	-100.0	-100.0	-100.0
F	0.30	3.3	203.3	83.3
D-F	3.12	-66.0	-47.1	-15.7
Entire Fishery[c]	45.66	1.3	1.0	0.3
		Mean Fishing Mortality		
A	7.69	23.5	17.0	4.2
B	25.08	13.8	10.1	2.5
C	9.70	14.7	10.8	2.7
D	1.26	14.3	10.3	186.5
E	3.61	-100.0	-100.0	-100.0
F	0.46	13.0	234.8	91.3
D-F	5.33	-63.2	-45.0	-15.8
Entire Fishery[c]	50.29	6.0	4.4	1.1
		Maximum Fishing Mortality		
A	5.92	27.4	19.6	5.1
B	25.06	16.2	12.5	3.0
C	9.51	17.4	12.7	4.1
D	1.29	14.7	10.9	255.0
E	3.78	-100.0	-100.0	-100.0
F	0.47	17.0	244.7	134.0
D-F	5.54	-63.4	-44.9	2.5
Entire Fishery[c]	48.38	7.2	5.3	3.6

[a] For area definitions, see footnote (a) to Table 3.

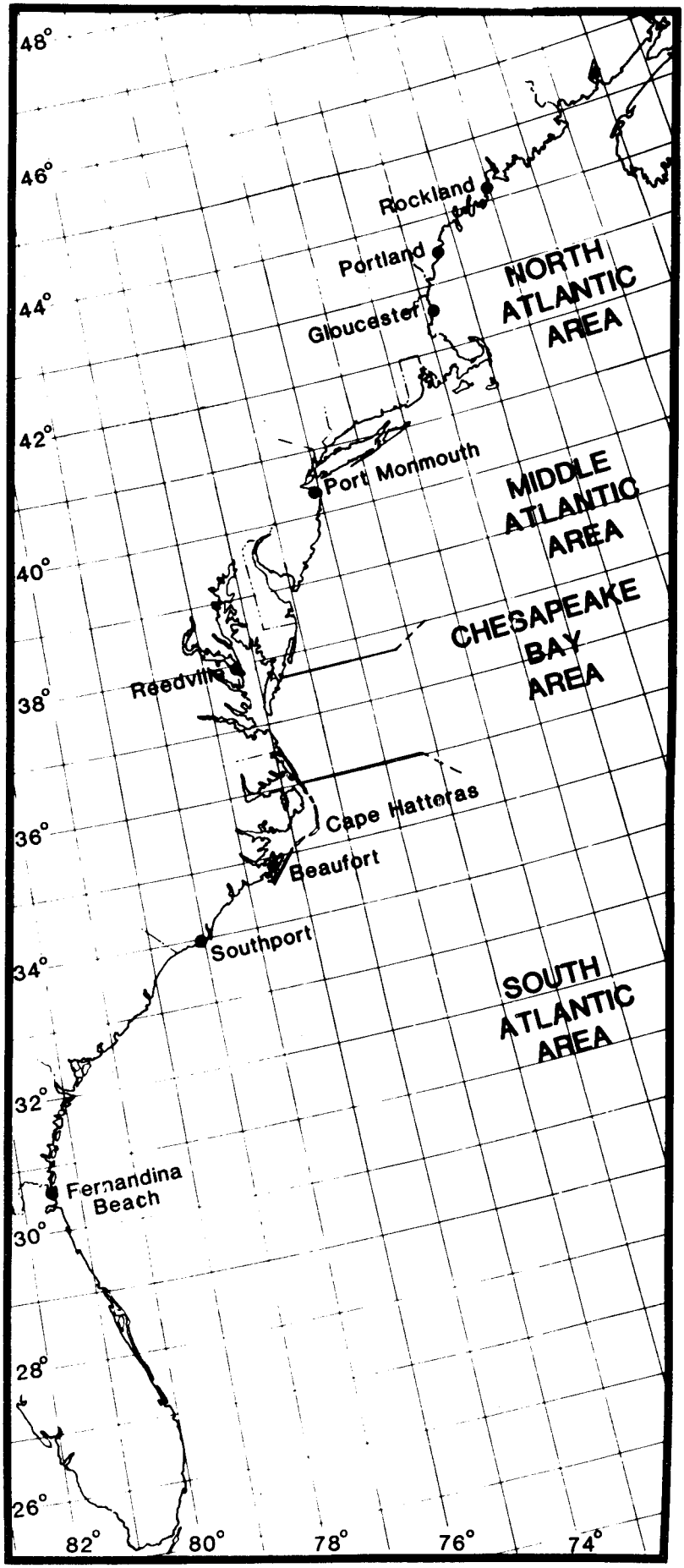
[b] Hypotheses are defined as follows: (I) no redistribution of fishing effort from Area E, (II) all fishing effort from Area E is redeployed into Area F, and (III) all fishing effort from Area E is proportionally redeployed to Areas D and F.

c The sum of area is slightly different from the overall total due to the nature of the yield-per-recruit program (MAREA), which calculated Y/R for individual area and then calculates overall Y/R instead of summing the areas. Thus, differences are due primarily to using a separate set of weights derived from the entire fishery.

FIGURE LEGENDS

Figure 1. Location of Atlantic menhaden processing plants along the Atlantic coast during the 1978 through 1982 fishing seasons.

Figure 2. Von Bertalanffy growth curves for Atlantic menhaden from inside waters (D), proposed closed corridor (E), and outside waters (F) between Cape Henry, VA, and Cape Fear, NC, during the fourth quarter. See Table 8 for parameter values and Eq. (2) for von Bertalanffy growth equation.


48°
46°
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42°
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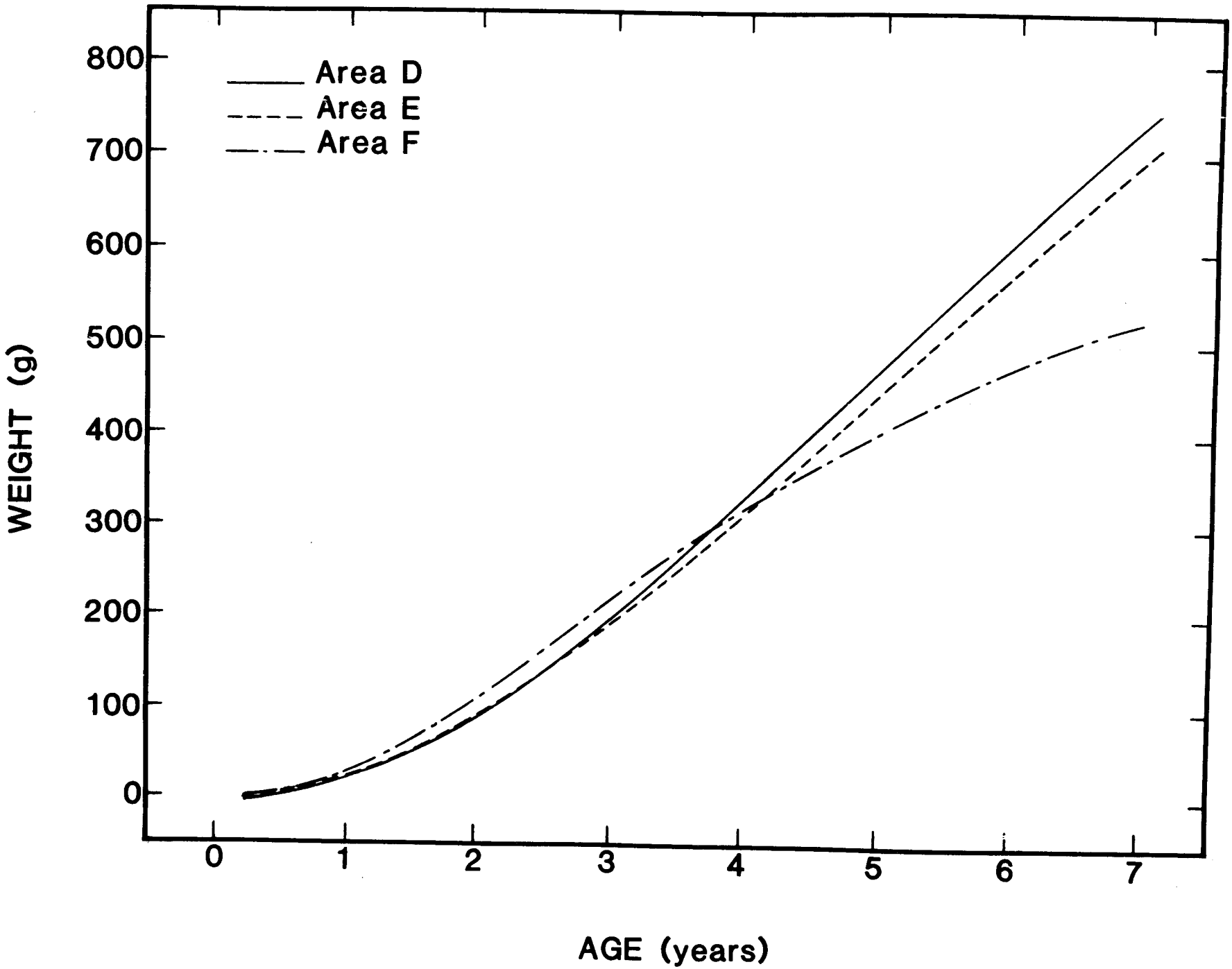
74°
Rockland
Portland
Gloucester
NORTH ATLANTIC AREA
Port Monmouth
MIDDLE ATLANTIC AREA
CHESAPEAKE BAY AREA
Reedville
Cape Hatteras
Beaufort
Southport
SOUTH ATLANTIC AREA
Fernandina Beach


Area D
Area E
Area F
WEIGHT (g)
800
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
AGE (years)