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July 1986

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
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National Marine Fisheries Service
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ABSTRACT

This report contains summary information on menhaden and coastal herrings made available during a stock assessment workshop held in 1984. Separate sections are included for Atlantic and Gulf of Mexico menhaden. The coastal herrings section describes information available on several species of engraulids, clupeids, and carangids. Each section includes description of the fishery, stock structure, stock status, effect of current management practices, and recommendations.

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INTRODUCTION

Summary information on menhaden and coastal herrings was made available at the Second Southeast Fisheries Center Stock Assessment Workshop held in Miami, FL, 4-8 June 1984. This information is divided into three parts in this report: 1) Atlantic menhaden, 2) gulf menhaden, and 3) coastal herrings. For each of these, description of the fishery, stock structure, stock status, effect of current management practices, and recommendations are summarized, updating material in Powers (1983). The coastal herrings section includes descriptions of several species of engraulids, clupeids, and carangids.

This Menhaden and Coastal Herrings Working Group report is being issued independently, because the full Southeast Fisheries Center Stock Assessment Workshop document will not be printed and there is no Southeast Fisheries Center stock assessment workshop is scheduled scheduled for 1986. We provide the following information to other researchers and resource managers to facilitate information transfer.

Data presented in the body of this report are as discussed at the June 1984 meeting. Some references have been redated to reflect current status, though reference is made to the original workshop documents (SAW/84/MCH/-). For more recent fishery statistics and selected special reports the reader may contact Douglas S. Vaughan (919/728-8761).

ATLANTIC MENHADEN

I. DESCRIPTION OF FISHERIES

I.1. Catch Trends

Details of the historic landings and distribution of fleet activity are provided in the Atlantic menhaden management plan (ASMFC 1981) and in Ahrenholz et al. (1985). Purse-seine landings of Atlantic menhaden caught between 1940-83 range from 161 to 712 KMT. Over the last decade, landings were between 250-419 KMT (Table 1). Over 90% of the landings in 1979-83 occurred in New Jersey, Virginia, and North Carolina ($\overline{x}$ = 350 KMT), and the Chesapeake Bay fishery dominates the industry today (Table 2). Distinct seasonal trends are evident in the landings, with peak activity in July-August (Fig. 1).

Landings by other gear principally enter the market as crab or lobster bait and as pet food. They are minor in comparison with the purse-seine landings (about 5% of total).

I.2. Effort Trends

Number, type, location, and intensity of vessel fishing effort in the 1955-83 period have varied considerably (Table 1 and ASMFC 1981). Distinct changes have occurred in various geographic reporting areas. Vessels operating in the North Atlantic area have varied from 40 in 1956, 0 in 1967, to 5 in 1980-81. The Middle Atlantic area declined from 48 in 1955 to 1 vessel in 1970, 4-6 vessels for 1976-81, and 0 vessels since 1982. The number of vessels in Chesapeake Bay area has been more stable (18 or more each year) and included between 21-24 vessels since 1976. The South Atlantic area has decreased from 34 vessels in 1955 to between 10 and 12 active vessels since 1970. The North Carolina fall fishery declined from 64 vessels in 1957 to 4 in 1973 and in the last four seasons has averaged about 18 vessels.

Present day vessels differ significantly from those of the 1950's. The modernized vessel is steel hulled with refrigerated holds; additional improvements include spotter planes, power blocks, and synthetic net webbing. The modern vessel typically carries a crew of 16. Changes in the vessel characteristics and fishing technique, particularly the use of spotter planes, have made it difficult to develop and estimate an effective unit of fishing effort for application throughout the fishery. Nominal effort (Table 1) is the apparent or deployed amount of effort, herein defined as a vessel-week of activity. Over the last 9 years, effort has averaged about 1,140 vessel-weeks per season. The Chesapeake Bay area has contributed between 552-667 vessel-weeks of effort since 1972.

II. STOCK STRUCTURE

Based upon tagging and age composition data from commercial landings, the population of Atlantic menhaden from Florida to Nova Scotia is considered a unit stock (Nicholson 1972, 1978a; and Dryfoos et al. 1973). There is some evidence, however, for alternate hypotheses of stock structure from meristics and electrophoretic studies (Ahrenholz et al. 1985). The population exhibits a complex migratory pattern by size and age with larger and older individuals occurring in northern waters. A north-south migration by most members of all age groups takes place in spring and fall. The Working Group accepts the hypothesis of a unit stock for Atlantic menhaden.

III. STOCK STATUS

III.1. Population Parameters

III.1.1. Natural Mortality Rates

The estimated value of M from an iterated least squares regression of Z on effective effort was 0.37 (Schaaf and Huntsman 1972). Dryfoos et al. (1973) obtained an estimate of 0.52 from analysis of tagging data. Deriso et al. (1980), with cohort analysis and weighted least squares nonlinear regression analyses of mark-recovery data, estimated a range for age specific M's from 0.15 to 0.54 and later adopted 0.5 ± 0.09 (1 standard deviation) (Ruppert et al. 1981). Present analyses employ 0.45 for age 1 and older fish (Ahrenholz et al. 1985). Preliminary sensitivity assessments by Ruppert et al. (1981) suggested that natural mortality rate was not critical to performance of their simulation model (MENSIM) relative to decision making for management policy. It is, however, a sensitive parameter when estimating catch. III.1.2. Growth Estimates

Data on growth rates were presented in ASMFC (1981) and Reish et al. (1985). Season and density-dependent effects on growth in the first year of life have led to development and use of area specific length-weight relationships and von Bertalanffy growth curves (Reish et al. 1985). Their analyses suggest a strong density-dependent growth relationship in recent years, but this is not nearly so evident for previous years when the population was declining. More recent analyses suggest that mean weight at age, since at least 1973, is lower than would be expected by density-dependent factors alone. Possible causes of this observation are discussed in Ahrenholz et al. (1985).

III.2. Catch Per Unit Effort Trends (CPUE)

Landings per vessel-week (Table 1) ranged from 147 MT in 1967 to 421 MT in 1983. CPUE has exceeded 310 MT/vessel-week since 1979 and has generally been increasing since the mid-1970's. Due to the changes in vessel characteristics and fishing technique, CPUE data are not considered representative of trends in abundance for the time series as a whole.

III.3. Stock Assessment Analyses

III.3.1. Production Model Analyses

Estimates of MSY in ASMFC (1981), Schaaf (1975, 1979), and Schaaf and Huntsman (1972) ranged from 370 to 560 KMT (the lower figure is based upon recent values for age at entry and effort). Recent estimates of MSY from Ahrenholz et al. (1985) are 414 and 557 KMT.

Factors such as variable growth rate and recruitment level, change in age structure, and change in vessel efficiency affect the estimates; thus estimates of MSY are considered of limited value for fishery management and should be integrated into plans with caution (ASMFC 1981). Based upon MENSIM, a population simulation model (Ruppert et al. 1981 and Nelson and Ahrenholz 1986), sustainable yields of 475-525 KMT are considered possible, but higher values could only be sustainable if the age structure could be modified, i.e., through an increase in the average age at capture.

III.3.2. Yield Per Recruit (Y/R)

Overall Y/R under current conditions (1976-78 seasons) was 57 grams (Ahrenholz et al. 1985). Y/R has been decreasing since 1971; the proportional contribution of younger age groups to the landings has been increasing and the average size at age is decreasing. Both reduced growth and redirection of effort towards younger fish are contributing to the reduced levels in yield per recruit.

Given the hypothetical case of no fishing, maximum biomass would occur at approximately age 3.25 (Fig. 3). Increases in Y/R from present levels are expected with reduced fishing mortality and/or increased age at entry (Table 3). Changes in the age at entry would change the current allocation of Y/R as well as the catch in the five fishing areas as would reduced effective effort (Table 4), increasing the overall fishery landings with an increased age at entry, but decreases the landings of the North Carolina fall fishery.

III.3.3. Virtual Population Analysis (VPA)

VPA analysis has been applied to Atlantic menhaden data collected since 1955. It includes quarterly estimates of fishing mortality and population size to accurately reflect the seasonal nature and sequence of the purse-seine fishery. The rate of exploitation is high for Atlantic menhaden, ranging from 26 to 80% and averaging over 60% for ages 2 and older in recent years. A variety of techniques has been employed to develop starting F values for the analyses. These include several iterative techniques to approximate slopes of catch curves. Pope's (1972) approximation method (cohort analysis) has been applied by Deriso et al. (1980) using M of 0.52. Very similar results have been obtained regardless of the method employed to select the starting F due to the high mortality experienced by all age groups (see Deriso et al. (1980) and Ahrenholz et al. (1985) for area and age specific values).

III.3.4. Stock Recruitment Analyses

Recruitment since 1970 has varied by a factor of five. Summaries of recruitment data are contained in Ahrenholz et al. (1985), Deriso et al. (1980), and Nelson et al. (1977). Environmental influences on recruitment are great and may mask any existing spawner-recruit relationship. Present data do not suggest a strong spawner-recruit relationship during the period 1955-78 (Ahrenholz et al. 1985; Table 7, Fig. 3). Based upon historic behavior of other similar fishery resources, the data suggest a low spawning stock size in recent years. Data reflect typical clupeid variability (r strategist). Based upon cohort analysis and recent landings data, above average recruitment has been shown for the 1975, 1979, and 1981 year classes.

III.4. Current Status

Recent descriptions are given in ASMFC (1981). Stock abundance has apparently increased due to moderate to high levels of recruitment, especially the 1979 and 1981 year classes. The age composition is strongly truncated and the present fishery is heavily dependent upon age 1 and 2 fish (pre-spawners); thus, yield/recruit is now lower than it was during the 1974-76 period. Higher levels of yield per recruit are attainable with reduced fishing effort and increased age at entry.

The National Marine Fisheries Service (NMFS) forecast for the 1984 season was 402 KMT (975 vessel-week effort). This forecast is below most estimates of MSY for this fishery. The 1984 landings will contain a similar age composition in each area compared to recent years.

IV. EFFECT OF CURRENT MANAGEMENT PRACTICES

The independent coastal states from Maine to Florida have jurisdiction over the resource and fishery (see ASMFC 1981, Section 3). Since the catch is made mostly in internal waters and the territorial sea, Magnuson Fisheries and Conservation Management Act (MFCMA) provisions do not apply. The amount of regulation or control exercised varies from state to state. No state limits the amount of effort (vessels) or catch. As of summer 1984, some states have closed seasons (Virginia, New Jersey, and New York) and two states (Maryland and Delaware) do not permit any fishing by purse seine. Mesh size is controlled only in Virginia and South Carolina, but most states do not restrict length or depth of the net. Most states have designated areas where purse-seine fishing is not permitted and, in general, waters near more highly populated urban areas are restricted.

Area specific availability of the resource, company policy and economics have had an overriding influence on the fishery. Stock assessments by NMFS provide the biological measures of resource response to the present harvesting practices throughout the range of the fishery. The management plan, approved by ASMFC, specifies that NMFS conduct stock assessment studies and that the Atlantic Menhaden Advisory Committee evaluate the effects of any management measures adopted and offer recommendations for management actions.

V. RECOMMENDATIONS

V.1. Data Needs

ASMFC (1981) presented general data requirements in support of the management program (see Section 10). Essential elements include age structure of the catch, size at age, and tagging programs. The menhaden industry also provides daily catch records, plant production data, and Captain's Daily Fishing Reports, which comprise the landings and effort data bases needed for assessment purposes. The Captain's Daily Fishing Reports and spotter aircraft activity records are believed to be of potential value in the development of a measure of effective effort that would be adequate for management purposes (Condrey 1982).

V.2. Research

An array of potential research topics were included in ASMFC (1981). Essential components specified were development of a basis for measuring effective effort and development of a predictive capability for landings based upon fishery-independent estimates of abundance of young menhaden. The Atlantic Menhaden Management Board (AMMB) of ASMFC has also requested mesh selectivity studies to provide a basis for possible future mesh regulation. These studies are now in progress on Chesapeake Bay by East Carolina University, Greenville, N.C. Further applications of the tagging data base should be made for refinement of stock assessment parameters. Additional research effort should be placed on identifying the causes of small sizes at age noted by Ahrenholz et al. (1985) and determine if any of these causes can be corrected through management. Uncertainty in the data collected, parameters estimated, and models selected for stock assessment should also be simulated using Monte Carlo approaches for determining the effects of these uncertainties on model predictions (Vaughan 1984). Parameter uncertainty in MENSIM has already been used to assess managerial risks (Ruppert et al. 1985).

V.3. Management

On 19 May 1982, the AMMB approved a reduction of the fishing season in each reporting area by four weeks to be effective in 1983. Y/R analyses projected a gain of yield for the entire fishery of 16.7 - 22.7 KMT. The "loss" to the North Carolina fall fishery would be 6.3 - 8.5 KMT. With 1976-78 effort and age at entry Y/R would rise 5.7% to 55.28 g. Opening and closing dates proposed are as follows:

	Opening Period	Closing Period
North Atlantic	5/17 - 5/23	10/04 - 10/10
Middle Atlantic	5/17 - 5/23	10/11 - 10/17
Chesapeake Bay	5/17 - 5/23	11/08 - 11/14
South Atlantic and North Carolina Fall Fishery	4/12 - 4/18	12/13 - 12/19

Implementation of the above measure will require a combination of legislation and special regulations depending upon state fishery agency authority. As of summer 1984, New Jersey, New York, and Connecticut have approved the measure. Rhode Island will respond with pending legislation. Maryland has prohibited menhaden purse-seining since World War II, and Delaware acted unilaterally and now prohibits all menhaden purse-seining in its territorial waters (3 miles). Virginia is considered in compliance, while North Carolina, and states to the South have taken no action.

The AMMB adopted no other management recommendations at its 19 May 1982 meeting, the rationale being to take one action and evaluate the effects of that measure before confounding the interpretation of fishery and stock by adopting other concurrent measures. The Atlantic Menhaden Advisory Committee (AMAC), through data collected and analyzed by NMFS, is to evaluate the effectiveness of the action after it is implemented.

The Working Group recommends that the various coastal states implement the season as called for by the AMMB and ASMFC action. Future actions should be directed towards additional increases in Y/R as called for in the management plan. Correction of the growth overfishing problem will increase potential long-term yield, broaden the age structure, increase prospects for good recruitment, and tend to stabilize landings.

GULF MENHADEN

I. DESCRIPTION OF FISHERIES

I.1. Catch Trends

Details of historic landings are provided in the gulf menhaden management plan (Christmas and Etzold 1977, Christmas et al. 1983) and in Nelson and Ahrenholz (1986). Landings of gulf menhaden caught by purse seine increased fairly steadily from 9 KMT in 1946 to 728 KMT in 1971 (Table 6). From 1972 to 1983, landings fluctuated between 447 and 923 KMT, with record landings occurring in 1982 and 1983. The bulk of the present day purse-seine landings occur in Louisiana (82%) and the remainder in Mississippi (18%). Historically, some landings were made in Florida and Texas. The landings currently occur from mid-April to mid-October with peaks occurring in June, July, or August, depending on weather and other fishing conditions (Fig. 5).

The reported landings of gulf menhaden are from purse seines. A relatively small amount of unreported catch for commercial and recreational bait also occurs.

I.2. Effort Trends

During 1964-83, the number of vessels in the fishery has fluctated between 65 and 82 (Nelson and Ahrenholz 1986). During the development of this fishery, many modernization changes were made to the vessels and fishing gear. Spotter aircraft were introduced in the late-1940's, which greatly facilitated locating fish schools. Refrigerated holds were added in the mid-1950's, which allowed the carrier vessels to stay out longer and range farther from their home port. Vessels currently range from eastern Texas coastal waters to the Florida panhandle, but the bulk of the catch occurs in Mississippi and Louisiana waters. More detailed descriptions are contained in Christmas et al. (1983) and Nicholson (1978b).

Nominal effort for the gulf purse-seine fishery is expressed in terms of vessel-ton-weeks. Effort has gradually increased from 1964 through 1983, although the number of vessels has not. This is due to more vessels fishing during the entire season and the progressive introduction of larger, more efficient vessels as older ones are retired.

II. STOCK STRUCTURE

The gulf menhaden fishery is believed to exploit a single stock or population of fish. Although tagging of pre-emigration juveniles indicates little if any exchange of fish from east and west of the Mississippi River delta (Kroger and Pristas 1975; Ahrenholz 1981), unpublished meristic studies do not indicate separate populations on each side of the Mississippi River delta (Christmas et al. 1983). The working group accepts the one stock hypothesis at this time for stock assessments of gulf menhaden.

III. STOCK STATUS
III.1. Population Parameters

III.1.1. Natural Mortality Rate

Recent analyses of gulf menhaden tag-recovery data provided estimates of M ranging from 0.7 to 1.6/yr and averaging 1.1/yr (Ahrenholz 1981). Current population dynamics analyses use the value 1.1/yr.

III.1.2. Growth Estimates

Nelson and Ahrenholz (1986) fitted a von Bertalanffy growth equation to quarterly mean weight at age data. The fitted parameters were: L_∞ = 252.9 mm; K = 0.47/yr; and t_0 = 0.36 yr. The weight-length relationship is:
$\log_e W = 3.2669 \log_e L - 12.1851$.

III.2. Catch Per Unit Effort Trends (CPUE)

Landings per vessel-ton-week range from 3.71 MT in 1946 to 0.78 MT in 1967 (Table 6). No consistent trends are evident in the CPUE values in the gulf menhaden fishery. The group noted potential limitations in the CPUE time series due to changes in vessel characteristics and fishing techniques.

III.3. Stock Assessment Analyses
III.3.1 Production Model Analyses

A number of MSY estimates are available from earlier studies. Chapoton (1972) obtained an estimate of 430 KMT for the 1946-70 seasons, using the Schaefer model. Schaaf (1975) obtained an estimate of 478 KMT by incorporating data from additional seasons, 1971 and 1972. More recently, Nelsona and Ahrenholz (1986) obtained a Schaefer estimate of 553 KMT for the 1946-79 seasons, and an estimate of 585 KMT (Fig. 6) by incorporating recent population fishing mortality rates, growth rates, and the spawner/recruit relationship into a population simulation model. Incorporation of 1980-83 season catch data would undoubtedly result in an even higher MSY estimate from the Schaefer model. The Working Group cautions that MSY estimates are considered of limited value in fishery management for reasons given with Atlantic menhaden (III.3.1).

III.3.2. Yield Per Recruit (Y/R)

Yield per recruit estimates obtained from a Ricker-type yield-per-recruit model (Epperly et al. 1979) are provided in Nelson and Ahrenholz (1986). With average fishing mortality rates observed for 1964-1977 as estimated from VPA, yield per recruit was estimated to be 17.09 grams. Y/R could actually be increased with higher rates of fishing, as maximum biomass is obtained at age 1.5 years and the rate of natural mortality is quite high (Fig. 7). Attempts to increase Y/R have severe consequences, as results from population simulation studies by Nelson and Ahrenholz (1986) indicate that recruitment overfishing is likely to occur.

III.3.3 Recruitment Analysis

VPA estimates of annual numbers of gulf menhaden recruited at age 1 range from a low of 7.5 billion to a high of 25.4 billion for the 1964-77 year classes (Nelson and Ahrenholz 1986; Table 7). Research has been conducted in Louisiana on environmental influences upon survival of young fish (Christmas et al. 1983).

The spawner-recruit relationship is dome shaped, with moderate scatter about the curve (Fig. 8). Parameter estimates for a Ricker-type spawner-recruit equation are given in Table 7.

III.4.1. Current Status

The Gulf fishery is currently fully exploited and appears to be reasonably stable in view of the age composition, lifespan, and effects of environmental factors. Annual production, fishing effort, and fleet size appear reasonably balanced. NMFS forecast of landings for the 1984 season is 820 KMT. Caution is warranted since the forecast landing is about 270 KMT above recently estimated MSYs which range from 544 to 585 KMT. Although recent short-term harvests in excess of MSY do not appear to have been detrimental to the stock, long-term harvesting above MSY cannot be maintained given the current understanding of the resource and uncertainties concerning MSY. Increases in effort could lead to problems in sustained yield from the population.

IV. EFFECT OF CURRENT MANAGEMENT PRACTICES

The Gulf menhaden fishery is conducted principally within the territorial sea of the five coastal states (Florida to Texas). All states voted in favor of a cooperative management system under the Gulf States Marine Fisheries Commission (GSMFC) in 1977 (Christmas and Etzold 1977) and this system was revised and adopted in 1983 (Christmas et al. 1983). Management authority is vested in the individual states. Some regulations, such as length of fishing season (open and close date), are common in all states, but other regulations are area-specific, on a state or county basis. No state controls or limits the catch or effort of vessels. The management plan established an advisory committee composed of state, industry and NMFS representatives. This committee reviews the status of the fishery periodically as the season progresses, and if desired, meets to resolve a specific issue or receive specific updates. This committee reports to an implementation committee of the states and makes recommendations for changes in the fishery. The implementation committee acts upon recommendations and informs the management board (state fishery agency personnel) if and when any action is required.

No analysis of the effects of current management practices was performed by the Working Group. Area-specific availability of the resource, company policy and economics have had an overriding influence on the fishery. Stock assessments by NMFS provide the biological measures of resource response to the present harvesting practices throughout the range of the fishery. The management plan specifies that NMFS conduct stock assessment studies and that the Gulf Menhaden Advisory Committee evaluate the effects of any management measures adopted and offer management recommendations as deemed necessary.

V. RECOMMENDATIONS

V.1. Data Needs

Christmas et al. (1983) identified data needs and priorities regarding future projects covering biological, economic, social and fishery related matters in the gulf menhaden purse-seine fishery. Top priority items include: (1) monitoring the fishery for information on age, size, catch, juvenile abundance, fishing effort, migrations, and in general the status of the resource; (2) determining, if possible, an effective unit of fishing effort; and (3) assessing the effects of environmental factors on recruitment and future harvests. These items are being researched by NMFS and considerable progress appears to have been made. The states principally are monitoring the estuarine habitat and performing law enforcement activities. Louisiana and Texas also conduct juvenile surveys and other biological research as noted above. Louisiana's surveys are directed toward shrimp but do provide data on gulf menhaden, while Texas' surveys are directed toward finfish including gulf menhaden. The Captain's Daily Fishery Reports are judged prime data sources for refinements to the current estimates of fishing effort and location of catch. Spotter aircraft data are believed to be of potential value in the development of a measure of effective effort that would be adequate for management application.

V.2. Research

Available data and analyses regarding the status of the gulf menhaden stock and the fishery are deemed adequate for assessment purposes. Additional analyses of the historical tagging data are ongoing and should provide further insights to understanding the resource. The bycatch in the Gulf of Mexico shrimp fishery should be examined for menhaden.

Further research to examine the effects of the environment upon recruitment is critical due to the dependence of the fishery upon age 1 and 2 fish. Coupled to this topic is the need to develop a predictive capability (index) for landings based upon pre-recruit abundance.

V.3. Management

Current landings are setting records. Earlier stock assessment analyses revealed that levels of biomass in the stock were present to produce these landings. But since stock assessments are based on historical data, an updated analysis is recommended to determine if current high harvests are due to:

(a) the observed increase in fishing effort as well as increases in the stock availability due to improved fishing conditions and/or changes in fishing patterns and strategy since the assessment work was completed, or

(b) some exceptionally large year classes in recent years resulting from good environmental conditions for fish prior to recruitment, or

(c) a combination of (a) and (b).

Given any of the above conditions, we do not believe the fishery will sustain these high levels of harvest; catches will eventually be reduced. If condition "a" (above) is prevalent, stock damage may occur and harvests would drop below levels which could occur if condition "b" (above) is prevalent where stock damage is not expected to occur.

Recent levels of fishing effort exceed those of the late 1970's. It is probably too great now, but this would have to be evaluated by way of appropriate stock assessment methods for current population/recruitment levels. Unfortunately, these analyses will tend to lag events in the fishery by several years.

Unlike the Atlantic menhaden, the gulf menhaden has a short life span (high natural mortality), which can result in rapid year-to-year changes in the fishable stock. Although increasing the number of year classes in the fishable stock is not biologically practical or suggested, caution is advised relative to the high F's evidenced and dependency upon very few age groups. Expansion of this fishery by effort or area is not recommended.

COASTAL HERRINGS

Several species of clupeids, engraulids and small carangids are abundant and collectively termed "coastal herrings". These species are very important prey for piscivorous marine fishes. None of the species is presently exploited significantly although their potential has been recognized for 25 or more years (Houde and Berkeley 1982). The underexploited species of major concern are thread herring, Spanish sardine, round herring, scaled sardine, anchovies, round scad, rough scad, and Atlantic bumper. Status of knowledge on these species is summarized in Reintjes (1980), Houde and Berkeley (1982), and Houde et al. (1983).

I. DESCRIPTION OF FISHERIES

Present catches (less than 4 KT annually) consist of landings in directed purse- and beach-seine fisheries. Bycatch (discard) on the Gulf of Mexico and South Atlantic coast probably contribute in excess of 30 KT. Some bycatch in the menhaden fishery also occurs (Guillory and Hutton 1982). In the Gulf area, additional harvest of about 5 KT may be made by Mexican and Cuban vessels. Data are principally developed from the Florida panhandle area where small directed bait fisheries occur.

II. STOCK STRUCTURE

Virtually no information is available for these species. The present assumption is that data developed off Florida may be applied throughout the Gulf of Mexico and extrapolation to the Atlantic coast may be required as a first approximation.

III. STOCK STATUS

Collectively, it has been estimated that the coastal herrings might sustain an annual harvest in the range of 1-2 million tons based upon Gulf of Mexico estimated stock biomass (Table 1 in Houde and Berkeley 1982). The estimated total present day harvest is only a small fraction (perhaps 5%) of the combined sustainable yield of these species. Data for catch and effort trend analysis are lacking. Thus, with no well developed fisheries, there is little stock assessment information on coastal herrings in the Gulf or Atlantic areas. Reintjes (1980) and Houde and Berkeley (1982) caution against application of vital parameter estimates derived from fished stocks in other areas of the world to stock assessment in the southeast United States. Stock assessment and life history information are presently being developed through Gulf and South Atlantic Fisheries Development Foundation (GSAFDF) projects and NMFS, Southeast Fisheries Center.

Information available was summarized by Reintjes (1980), Houde and Berkeley (1982), and Houde et al. (1983). Specific summations follow.

III.1. Engraulids

III.1.1. Bay Anchovy (Anchoa mitchilli)

This anchovy is a small (100 mm or less) and extremely abundant fish, considered important because it is a major prey for many commercial and recreational fishes. There is little information on this short-lived fish relative to growth rates, mortality rates, or estimates of standing stock.

III.1.2. Striped Anchovy (Anchoa hepsetus)

This anchovy is somewhat larger (>150 mm) and faster growing than bay anchovy, but apparently less abundant. There is little information on this fish relative to growth rates, mortality rates, or estimates of standing stock.

III.1.3. Silver Anchovy (Engraulis eurystole)

This anchovy is found farther from shore than the bay or striped anchovy. It grows to about 150 mm in length, but does not appear to be abundant. Little information is available relative to mortality rates, growth rates, or estimates of standing stock.

III.2. Clupeids

III.2.1. Round Herring (Etrumeus teres)

This herring, which is commonly 150-200 mm in length, is probably one of the most abundant clupeids in the Gulf of Mexico. However, because it commonly occurs offshore and does not form surface schools, it is relatively unavailable for exploitation. There are directed fisheries for round herring in Japan and South Africa, but these are likely to be different populations. The estimated potential yield for round herring in the Gulf of Mexico (assuming M is between 0.5 and 1.0/yr) ranges from 150 to 1500 KMT (Houde and Berkeley 1982).

III.2.2 Scaled Sardine (Harengula jaguana)

This small sardine (usually $\leq$ 200 mm in length) occurs in small schools in state jurisdictional waters. Small catches are made by the pet food and bait fisheries. Estimated potential harvest for this sardine is from 140 to 275 KMT (Houde and Berkeley 1982). No mortality rate estimates are available for this species.

III.2.3. Thread Herring (Opisthonema oglinum)

This herring is relatively abundant in coastal waters and over the inner continental shelf of the Gulf of Mexico and South Atlantic Bight. Houde et al. (1983) estimate maximum yield per recruit at 18.8 g with F_{max} = 3.3/yr, a recruitment length of 105 mm FL, and M = 0.82/yr. Little gain in yield is expected beyond F levels of 1.5/yr (Houde et al. 1983, Figure 2) where mean weight and age in the fishery would be 27.8 g and 1.2 yr, respectively. Size at age data and age distribution of landings for recent fishing levels are available (Table 8); maximum size may be 300 mm (Houde and Berkeley 1982).

III.2.4 Spanish Sardine (Sardinella aurita)

This sardine, widespread in the tropical and subtropical oceans of the world, is abundant in the shelf and coastal waters of the Gulf of Mexico and South Atlantic Bight. About 2 KMT of these sardines are landed annually by the bait and pet food fisheries. Houde et al. (1983) estimate maximum yield per recruit at 26.5 g with F_{max} = 2.7/yr, a recruitment length of 105 mm FL, and M = 0.90/yr. Little gain in yield is expected beyond F levels of 1.5/yr (Houde et al. 1983, Figure 2) where mean weight and age in the fishery would be 42.0 g and 1.42 yr, respectively. Size at age data and age distribution of landings for recent fishing levels are available (Table 8). Maximum size appears to be about 225 mm in the Gulf, while individuals in eastern Atlantic populations may exceed 300 mm (Houde and Berkeley 1982).

III.3. Carangids

III.3.1. Round Scad (Decapterus punctatus)

The round scad is relatively abundant and widely distributed over the continental shelf of the eastern Gulf of Mexico and South Atlantic Bight. Based on larval occurrences, it is believed to be less abundant in the central and northwestern Gulf. A directed bait fishery in Florida lands less than 500 MT annually. Houde et al. (1983) estimate maximum yield per recruit at 19.5 g with F_{max} = 5.2/yr, a recruitment length of 105 mm FL, and M = 0.92/yr. Little gain in yield is expected beyond F levels of 1.5/yr (Houde et al. 1983, Figure 2) where mean weight and age in the fishery would be 29.2 g and 0.95 yr, respectively. Size at age and age distribution of landings for recent fishing levels are available (Table 8).

III.3.2. Rough Scad (*Trachurus lathami*)

This species is not fished in the Gulf of Mexico. Additionally, there is no accurate information on which to estimate potential production (rough estimates of 40 to 1,700 KMT have been given).

III.3.3 Atlantic Bumper (*Chloroscombrus chrysurus*)

This species occurs in the bycatch of the shrimp fishery, but has no directed fishery. There are no reliable estimates on abundance, age structure, growth, or mortality rates.

IV. EFFECT OF CURRENT MANAGEMENT PRACTICES

No management practices are in place. Authority is mixed between states and MFCMA depending upon species and area in which fishery exists or might develop.

V. RECOMMENDATIONS

There is an obvious lack of stock assessment information for the coastal herrings. The most critical needs are to continue determining population age structures, growth rates and natural mortality rates, particularly for those species likely to undergo increased harvesting in the near future. This information will be most valuable if obtained before signficant fishing mortality occurs. Yield models then can be developed from which the stocks' abilities to sustain heavy fishing can be determined. From the standpoint of the fishery, lack of knowledge about availability and capture technology are major problems which retard development, in addition to uncertain social and economic factors. Catch and effort data should be obtained in the present small fishery and any expansion of the fisheries offshore should be carefully monitored to determine not only catch rates there but also to learn if different components of the stock are being exploited in the nearshore and offshore fisheries. There are important questions about stock identity for all of the coastal herrings which need to be addressed if significant fishing should begin. Finally, all of the coastal herrings are important as foods of predator fishes in the Gulf of Mexico and South Atlantic Bight. Their role in trophic dynamics and their importance in sustaining the predator populations need to be understood. The interactions among coastal herrings, particularly the potential for competition or the possibility of species replacement, when one or more species is heavily fished, should be recognized.

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Table 1. Fishing effort and catch in the Atlantic menhaden fishery, 1955-83 (Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, NC 28516, unpubl. data).

Year	Fishing Effort (vessel-weeks)	Total Catch (thousands of MT)	Catch per vessel-week
1955	2748	641.4	233.4
1956	2878	712.1	247.4
1957	2775	602.8	217.2
1958	2343	510.0	217.7
1959	2847	659.1	231.5
1960	2097	529.8	252.6
1961	2371	575.9	242.9
1962	2351	537.7	228.7
1963	2331	346.9	148.8
1964	1807	269.2	149.0
1965	1805	273.4	151.5
1966	1386	219.6	158.4
1967	1316	193.5	147.0
1968	1209	234.8	194.2
1969	995	161.4	162.2
1970	906	259.4	286.3
1971	897	250.3	279.0
1972	973	365.9	376.0
1973	1099	346.9	315.6
1974	1145	292.2	255.2
1975	1218	250.2	205.4
1976	1163	340.5	292.8
1977	1239	341.2	275.4
1978	1210	344.1	284.4
1979	1198	375.7	313.6
1980	1158	401.5	346.7
1981	1133	380.4	335.7
1982	948	382.4	403.4
1983	995	418.6	420.7

Table 2. Atlantic menhaden purse-seine landings by area, 1940-1983. (ASMFC 1981; R. Chapoton, NMFS, Beaufort, NC, pers. commun).

YEAR	North Atlantic	Middle Atlantic	Chesapeake Bay	South Atlantic	North Carolina Fall Fishery	TOTAL
	THOUSANDS OF METRIC TONS					
1940	16.8	91.1	35.3	37.9	36.6	217.7
1941	33.5	104.1	60.2	45.2	34.9	277.9
1942	14.6	77.7	21.9	32.9	20.1	167.2
1943	9.8	96.8	42.1	59.7	28.8	237.2
1944	27.5	122.6	32.2	46.9	28.7	257.9
1945	34.0	136.4	35.1	58.5	31.9	295.9
1946	42.9	183.8	57.6	40.8	37.3	362.4
1947	44.2	185.8	81.2	34.2	32.8	378.3
1948	44.4	137.4	68.3	55.8	40.6	346.5
1949	52.2	149.8	62.8	59.3	39.7	363.8
1950	49.3	143.0	63.1	20.0	21.8	297.2
1951	51.0	168.6	56.1	54.6	31.1	361.4
1952	58.1	193.7	45.7	86.0	26.4	409.9
1953	59.7	363.2	77.8	52.8	39.7	593.2
1954	64.9	335.7	126.0	39.6	41.9	608.1
1955	83.3	317.6	132.7	43.4	64.4	641.4
1956	98.5	378.3	94.0	68.6	73.7	712.1
1957	83.5	304.5	126.0	36.4	52.0	602.8
1958	36.0	211.1	151.3	41.3	70.3	510.0
1959	66.0	250.9	196.8	63.1	82.3	659.1
1960	66.4	256.0	108.5	36.7	62.2	529.8
1961	58.6	274.6	128.7	44.1	69.9	575.9
1962	64.7	249.9	155.1	42.2	25.8	537.7
1963	35.2	111.7	104.0	34.2	61.8	346.9
1964	15.0	35.2	134.1	46.5	38.4	269.2
1965	11.9	45.8	126.1	36.7	52.9	273.4
1966	1.8	6.0	115.6	24.5	71.7	219.6
1967	0.0	17.1	91.1	34.1	51.2	193.5
1968	6.7	26.2	115.5	33.6	52.8	234.8
1969	2.9	12.4	72.0	32.8	41.3	161.4
1970	4.3	11.5	182.9	42.4	18.3	259.4
1971	10.4	23.0	170.7	38.3	7.9	250.3
1972	14.5	54.6	245.5	45.9	5.4	365.9
1973	29.9	277.4[a]		37.2	2.4	346.9
1974	35.8	194.8		45.9	15.7	292.2
1975	23.1	149.8		59.5	17.8	250.2
1976	28.4	243.3		50.7	18.1	340.5
1977	15.0	244.1		49.8	32.2	341.1
1978	31.4	214.1		60.3	38.2	344.0
1979	29.4	230.7		61.6	54.0	375.7
1980	29.7	282.8		53.2	35.8	401.5
1981	21.8	215.9		79.1	64.5	381.3
1982	35.1	0.0	316.8[a]		30.5	382.4
1983	39.4	0.0	310.8		68.4	418.6

[a] Combined to retain confidentiality of landings data.

Table 3. Percent increase in yield per recruit for the Atlantic menhaden fishery based on average fishing mortality (F-multiple = 1.0) for the 1976-78 fishing season at an array of ages of entry, expressed as percentages of current yield per recruit (Ahrenholz et al. 1985).

Age at Entry	Percent Y/R at F-multiple				
	0.6	0.8	1.0	1.2	1.4
2.0	17	18	17	16	14
1.5	14	13	11	9	7
1.0	10	8	5	2	-1
0.5	7	4	(56.84 g)[a]	-4	

[a] Base value for calculation of percentage change

Table 4. Percent change in yield per recruit by area and for the overall Atlantic menhaden fishery at ages of entry of 1.0, 1.5, and 2.0 compared with yield per recruit (g) under the current age of entry (0.5) at average fishing mortality rate for the 1976-78 fishing season (D. Ahrenholz, NMFS, Beaufort, NC, pers. commun.).

		Age of Entry		
Area	Current (g)	1.0	1.5 Change (%)	2.0
North Atlantic	7.86	9.4	23.0	48.0
Middle Atlantic	8.19	9.4	22.2	42.6
Chesapeake Bay	24.34	9.4	12.5	13.7
South Atlantic	11.17	6.7	1.5	2.4
N.C. Fall Fishery	4.72	-25.4	-16.1	-46.6
TOTAL	56.84[a]	5.2	11.0	17.0

[a] The sum of the areas is slightly different from the overall total due to the nature of the yield per recruit program, which calculates Y/R for individual area and then calculates overall Y/R instead of simply summing the areas. Thus, differences are due to rounding.

Table 5. Estimated number of recruits by year class at age 0.5 and 1.0, estimated number of spawners that produced the year class, and estimated egg production from the spawning stock, for Atlantic menhaden (Ahrenholz et al. 1985).

	Number of Recruits ($X10^3$)		Number of Spawners	Number of Eggs
Year Class	Age 0.5	Age 1.0	($X10^3$)	($X10^{12}$)
1955	7,888,342	5,621,258	1,902,414.7	219.659
1956	8,999,656	7,153,549	1,358,982.4	147.047
1957	4,419,989	3,263,196	714,741.2	83.977
1958	18,612,316	14,767,294	549,652.3	57.768
1959	2,722,999	2,164,428	1,297,553.6	143.822
1960	3,786,692	2,958,923	793,658.0	76.642
1961	2,769,147	2,210,534	2,959,390.4	156.058
1962	2,841,268	2,222,880	1,293,097.0	106.781
1963	2,304,564	1,754,140	425,946.2	37.508
1964	2,764,796	1,938,001	255,156.0	21.466
1965	2,072,852	1,430,539	185,937.0	13.806
1966	2,879,544	2,001,871	116,018.6	7.552
1967	1,522,438	1,209,954	214,470.9	17.017
1968	2,319,215	1,710,666	172,444.5	13.053
1969	3,448,326	2,611,940	139,703.1	11.240
1970	1,755,217	1,382,032	152,402.4	12.056
1971	4,513,962	3,539,073	216,205.9	17.594
1972	3,516,016	2,760,443	298,955.5	31.279
1973	3,908,494	3,085,954	81,204.7	8.044
1974	5,197,484	3,866,593	87,491.6	6.076
1975	9,024,340	6,932,136	102,503.1	6.591
1976	6,953,329	5,297,439	156,147.7	7.575
1977	6,619,024	4,827,413	252,672.3	11.966
1978	6,040,678	4,404,267	563,449.0	18.864
1979[a]	10,322,177	6,890,589	547,169.7	18.389
1980	NE[b]	NE	672,445.4	26.045
1981	NE	NE	576,473.7	22.294

[a] Preliminary estimates

[b] No estimate

Table 6. Fishing effort and catch in the gulf menhaden fishery, 1946-83 (Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, NC 28516, unpub. data).

Year	Fishing Effort (Thousands of Vessel-Ton Weeks)	Total Catch (Thousands of Metric Tons)	Catch/Vessel-Ton-Week
1946	2.4	8.9	3.71
1947	21.0	33.9	1.61
1948	40.7	74.6	1.83
1949	66.2	107.4	1.62
1950	82.2	147.2	1.79
1951	94.2	154.8	1.64
1952	113.3	227.1	2.00
1953	104.7	195.7	1.87
1954	113.0	181.2	1.60
1955	122.9	213.3	1.74
1956	155.1	244.0	1.57
1957	155.2	159.3	1.03
1958	202.8	196.2	0.97
1959	205.8	325.9	1.58
1960	211.7	376.8	1.78
1961	241.6	455.9	1.89
1962	289.0	479.0	1.66
1963	277.3	437.5	1.58
1964	272.9	407.8	1.49
1965	335.6	461.2	1.37
1966	381.3	357.6	0.94
1967	404.7	316.1	0.78
1968	382.3	371.9	0.97
1969	411.0	521.5	1.27
1970	400.0	545.9	1.36
1971	472.9	728.5	1.54
1972	447.5	501.9	1.12
1973	426.2	486.4	1.14
1974	485.5	587.4	1.21
1975	538.0	542.6	1.01
1976	575.8	561.2	0.97
1977	532.7	447.1	0.84
1978	574.3	820.0	1.43
1979	533.9	777.9	1.46
1980	627.6	701.3	1.12
1981	623.0	552.6	0.89
1982	653.8	853.9	1.31
1983	655.8	923.5	1.41

Table 7. January 1 estimates of number of spawners, number of eggs produced by the spawning stock, biomass of the spawning stock, and number and biomass of recruits at age 1 for gulf menhaden (Nelson and Ahrenholz 1986).

Year	Number at Age (Millions) 2	3	4	Total Spawners (Millions)	Number of Eggs (Trillions)	Spawning Biomass (Metric Tons)	Resultant Recruitment (Millions)	Recruitment Biomas (Metric Tons)
1964	2,696.3	206.4	7.2	2,909.9	36.1	305,468	12,886.7	410,630
1965	1,749.9	138.2	9.7	1,897.8	23.7	200,150	7,519.5	239,421
1966	1,463.9	55.1	6.8	1,525.8	18.4	156,705	12,138.2	386,480
1967	722.2	19.0	-	741.2	8.8	75,118	12,186.7	388,025
1968	1,644.3	62.6	0.4	1,707.3	20.5	174,454	25,424.7	809,522
1969	2,026.9	58.7	-	2,085.6	24.8	211,752	16,396.8	522,074
1970	5,026.0	78.2	-	5,104.2	60.0	513,461	20,889.9	665,134
1971	3,472.8	382.4	6.2	3,861.4	49.0	412,808	12,618.5	401,773
1972	3,565.3	127.7	33.7	3,726.7	45.2	384,521	20,796.4	662,157
1973	2,365.8	239.0	3.4	2,608.2	32.8	277,323	19,889.0	633,266
1974	5,067.7	131.1	-	5,198.8	61.7	526,725	13,456.1	428,442
1975	4,376.3	879.9	7.3	5,263.5	70.5	588,668	(15,097.7)	(480,711)
1976	2,917.7	573.5	-	3,491.2	46.6	389,073	(24,466.7)	(779,020)
1977	(2,290.0)	238.8	76.2	(2,605.0)	(34.3)	(286,686)		
1978	(5,258.5)	(90.6)	19.2	(5,368.3)	(63.6)	(543,194)		

( ) Preliminary Estimates

Table 8a. Estimated lengths and weights at age for coastal herrings, based on 1981 and 1982 samples. Lengths were back calculated from otolith-fork length equations and von Bertalanffy relationship and weights were determined separately by year from weight-length relationships using von Bertalanffy estimates of fork length (Houde et al. 1983, Tables 2-4).

Species	Age	Fork Length (mm)		Weight (g)	
		Back-calculated	von Bertalanffy	1981	1982
Spanish sardine	1	130.4	131.0	29.5	27.6
	2	162.3	162.7	58.4	58.3
	3	179.2	179.5	79.6	81.9
Thread herring	1	108.2	113.9	22.7	25.4
	2	152.4	146.1	50.7	52.4
	3	171.0	168.0	79.5	78.6
	4	179.5	183.0	104.7	100.8
	5	186.8	193.3	124.9	118.2
	6	202.7	200.3	140.0	131.1
Round scad	1	136.0	135.2	29.9	30.0
	2	159.7	158.9	50.0	51.1
	3	176.9	176.1	69.3	71.7

Table 8b. Age composition of 1981 and 1982 catches (pooled) of coastal herrings (Houde et al. 1983, Table 5). Ages based on otolith annuli counts.

Species	Age	Number in Samples	Estimated Percent in Age Group
Spanish sardine	0+	378	21.8
	1+	779	45.0
	2+	502	29.0
	3+	73	4.2
		1732	
Thread herring	0+	62	7.3
	1+	477	56.1
	2+	174	20.5
	3+	87	10.2
	4+	29	3.4
	5+	13	1.5
	6+	8	0.9
		850	
Round scad	0+	1659	75.1
	1+	420	19.0
	2+	127	5.7
	3+	3	0.1
		2209	

FIGURE LEGENDS

Figure 1. Landings of Atlantic menhaden by month in 1981-1983 (Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, NC 28516, unpubl. data).

Figure 2. Mean weight of Atlantic menhaden (weighted) at ages 1, 2, and 3, 1955-1981 (Ahrenholz et al. 1985).

Figure 3. Overall yield per recruit of Atlantic menhaden under current conditions (F-multiple of 1.0, and age at entry of 0.5) using average fishing mortality values by quarter and area for the 1976-1978 fishing seasons (Ahrenholz et al. 1985).

Figure 4. Numbers of Atlantic menhaden recruits by year class plotted against estimated egg production for year classes 1955-1978. Curves are nonlinear least squares results of fitting the Ricker (solid line) and Beverton-Holt (dot-dashed line) (Ahrenholz et al. 1985).

Figure 5. Gulf landings of menhaden by month in 1981-1983 (Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, NC 28516, unpubl. data).

Figure 6. Sustainable yield predicted by a deterministic population simulation model of the Gulf menhaden fishery at multiples of the average fishing mortality (F-multiple = 1.00) for the 1964-1977 fishing season (Nelson and Ahrenholz 1986).

Figure 7. Yield per recruit of Gulf menhaden under average conditions of growth and with multiples of average fishing mortality by 3-month interval (F-multiple = 1.00) for the 1964-1977 fishing seasons (average conditions indicated by ◘) (Nelson and Ahrenholz 1986).

Figure 8. Ricker spawner-recruit relationship for number of spawners and recruits at age 1 of Gulf menhaden estimated as of January 1, for the 1964-1976 Gulf menhaden year classes (R = S exp (8.83 - S)/3.22) (Nelson and Ahrenholz 1986).

Figure 1. Landings of Atlantic menhaden by month in 1981-1983 (Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, NC 28516, unpubl. data).

LANDINGS OF ATLANTIC MENHADEN (by month)

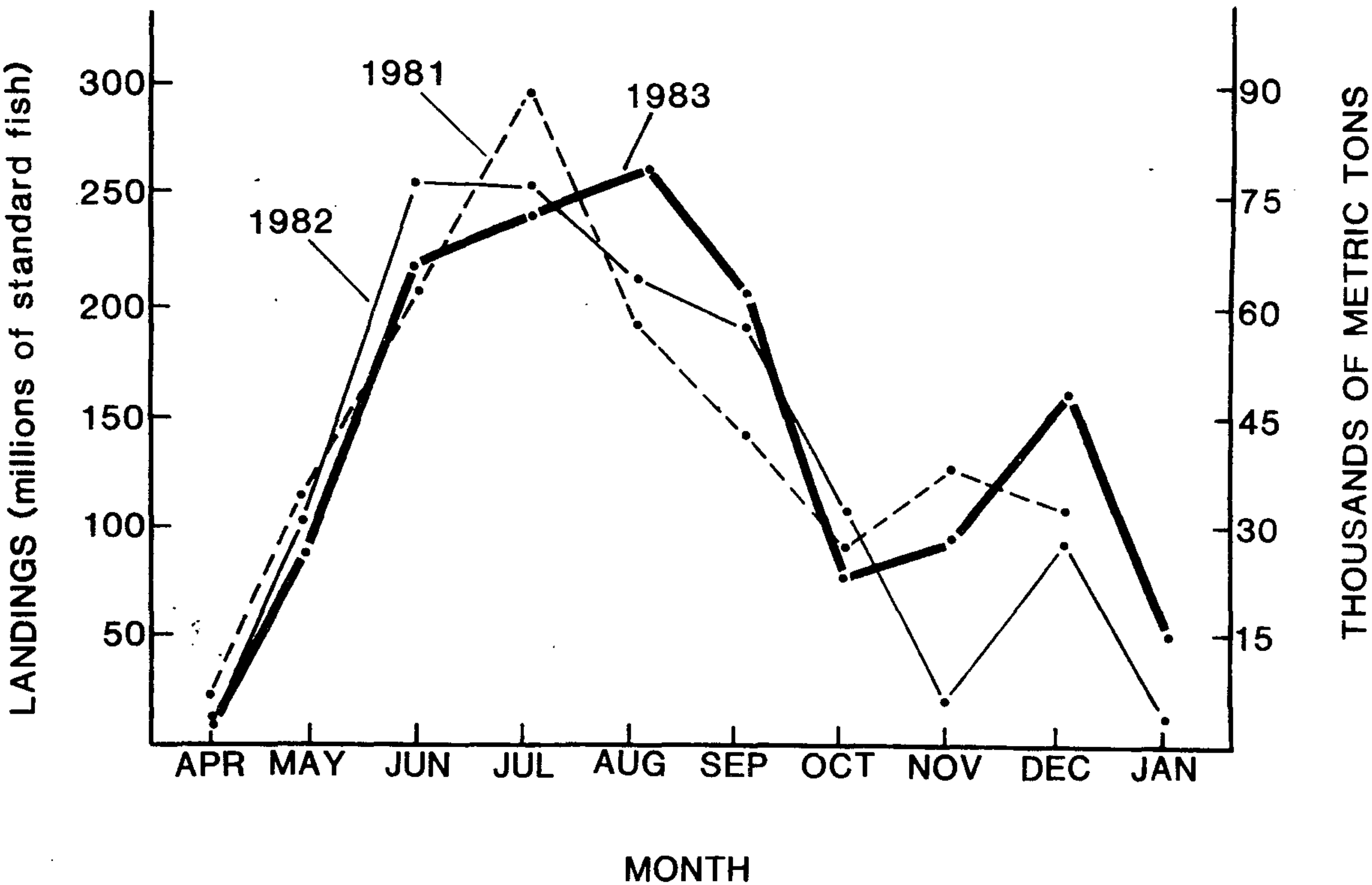


Figure 2. Mean weight of Atlantic menhaden (weighted) at ages 1, 2, and 3, 1955-1981 (Ahrenholz et al. 1985).

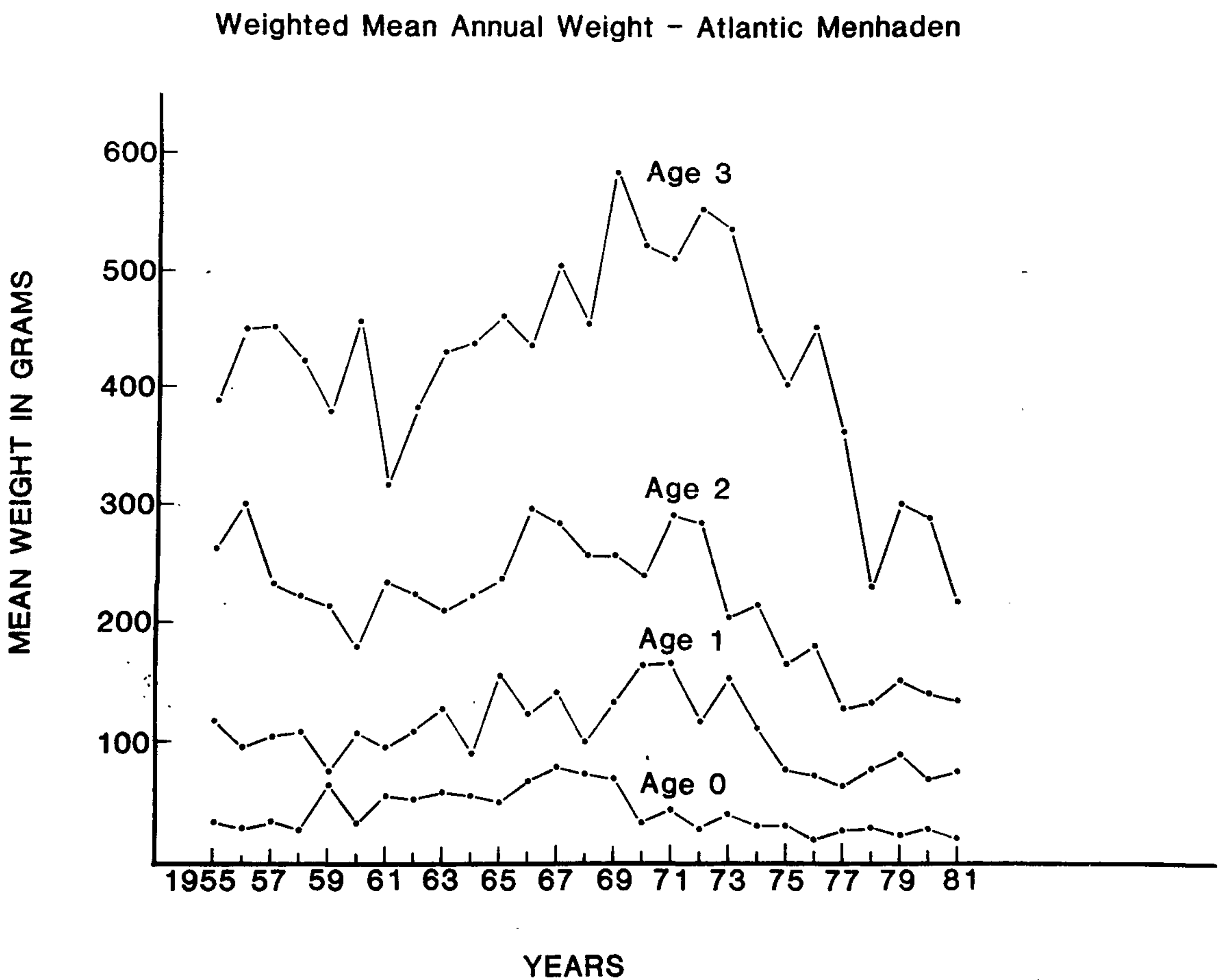

Weighted Mean Annual Weight - Atlantic Menhaden
MEAN WEIGHT IN GRAMS
600
500
400
300
200
100
Age 3
Age 2
Age 1
Age 0
1955 57 59 61 63 65 67 69 71 73 75 77 79 81
YEARS

Figure 3. Overall yield per recruit of Atlantic menhaden under current conditions (F-multiple of 1.0, and age at entry of 0.5) using average fishing mortality values by quarter and area for the 1976-1978 fishing seasons (Ahrenholz et al. 1985).

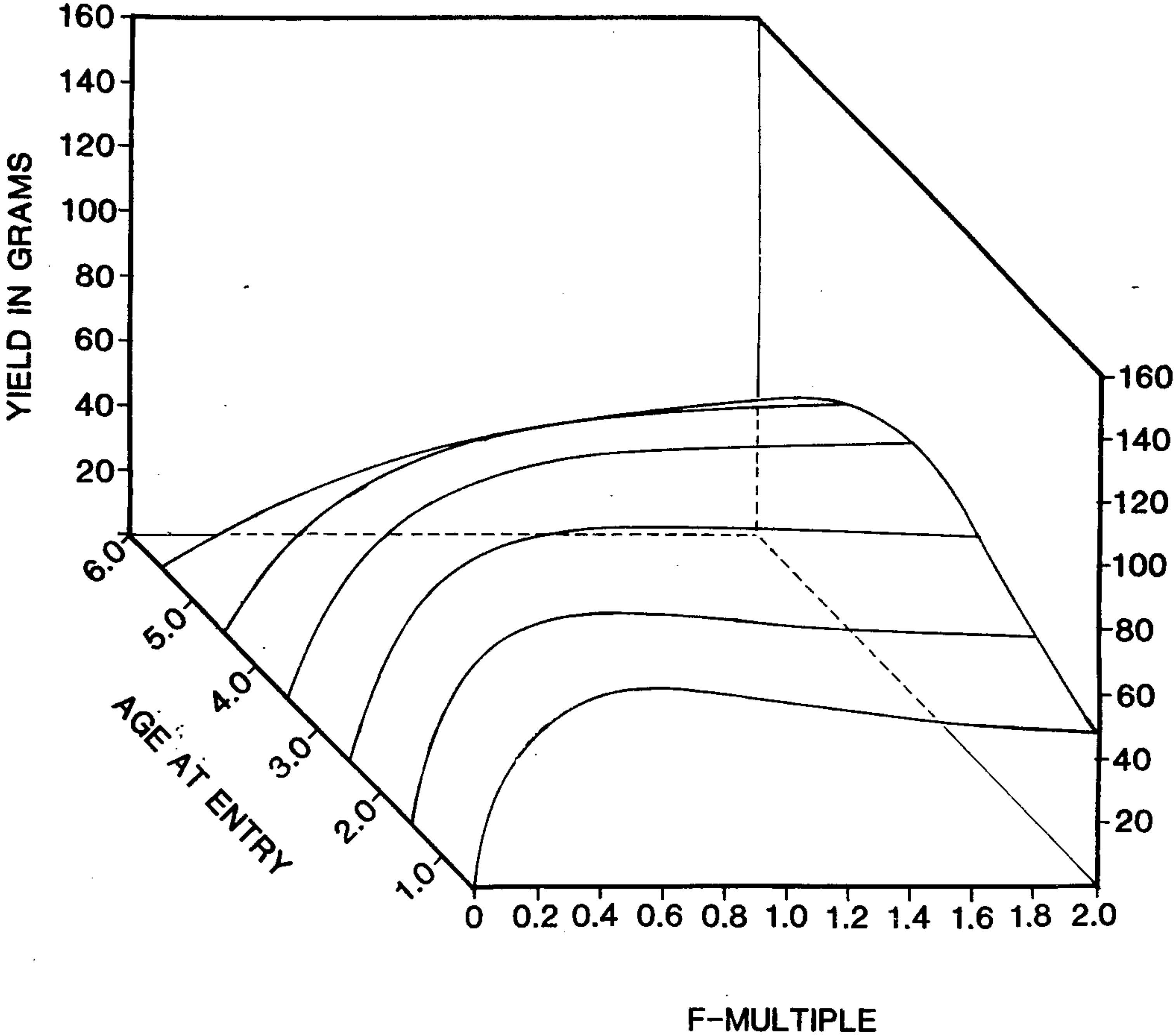

YIELD IN GRAMS
160
140
120
100
80
60
40
20
6.0
5.0
4.0
3.0
2.0
1.0
AGE AT ENTRY
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
F-MULTIPLE

Figure 4. Numbers of Atlantic menhaden recruits by year class plotted against estimated egg production for year classes 1955-1978. Curves are nonlinear least squares results of fitting the Ricker (solid line) and Beverton-Holt (dot-dashed line) (Ahrenholz et al. 1985).

Atlantic Menhaden Spawner Recruit Relationship

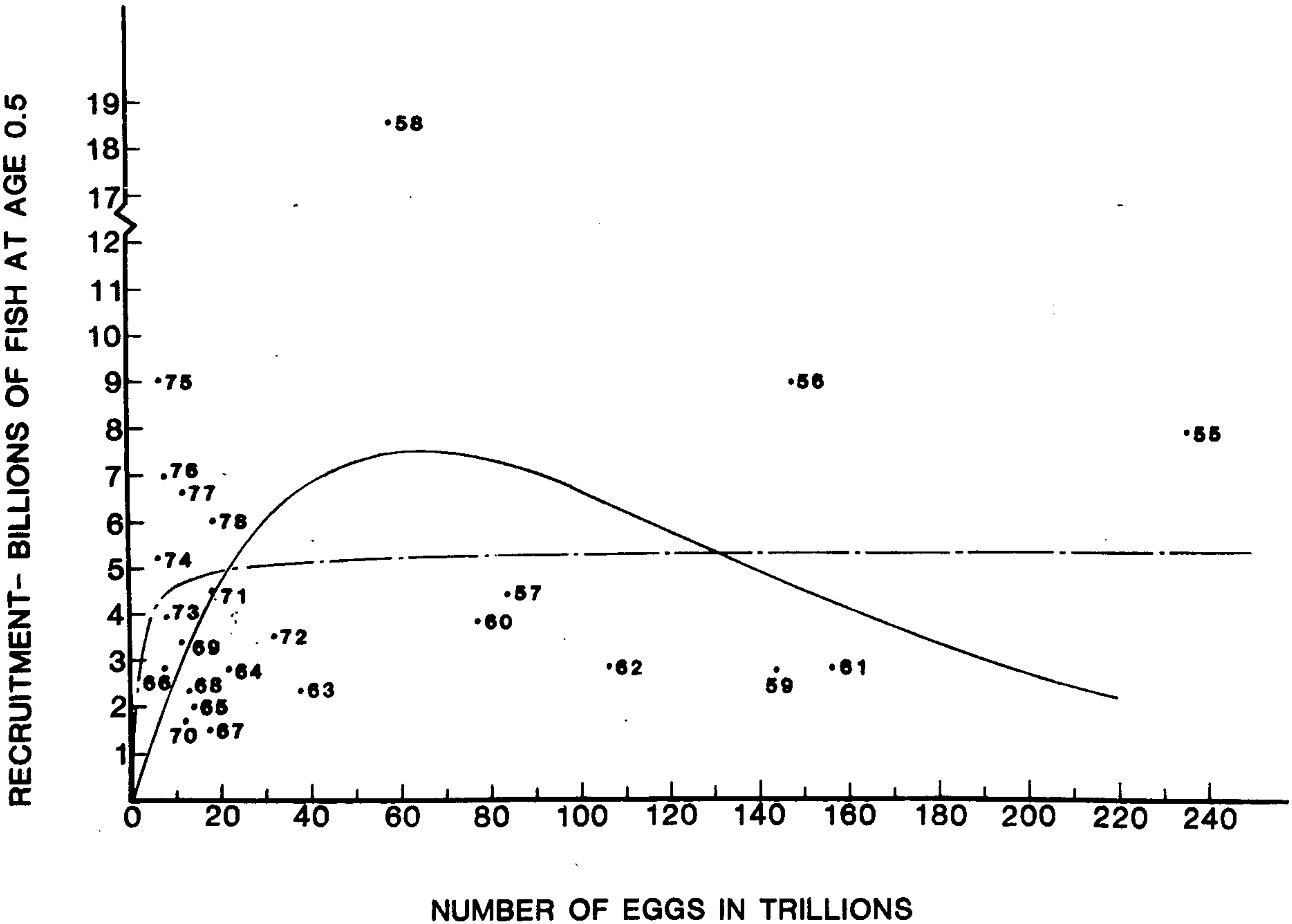


Figure 5. Gulf landings of menhaden by month in 1981-1983 (Natl. Mar. Fish. Serv., Beaufort Laboratory, Beaufort, NC 28516, unpubl. data).

LANDINGS OF GULF MENHADEN (by month)

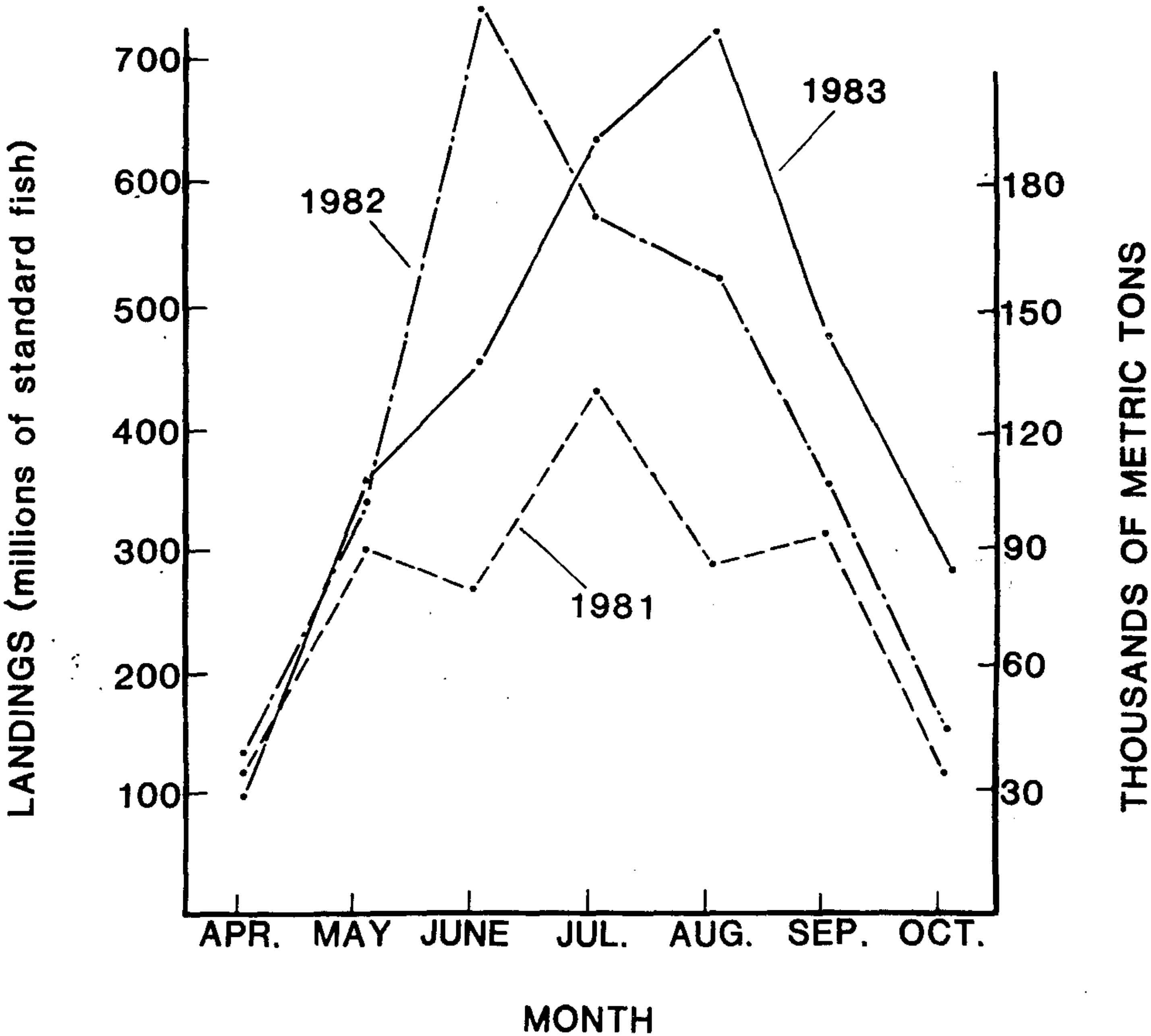
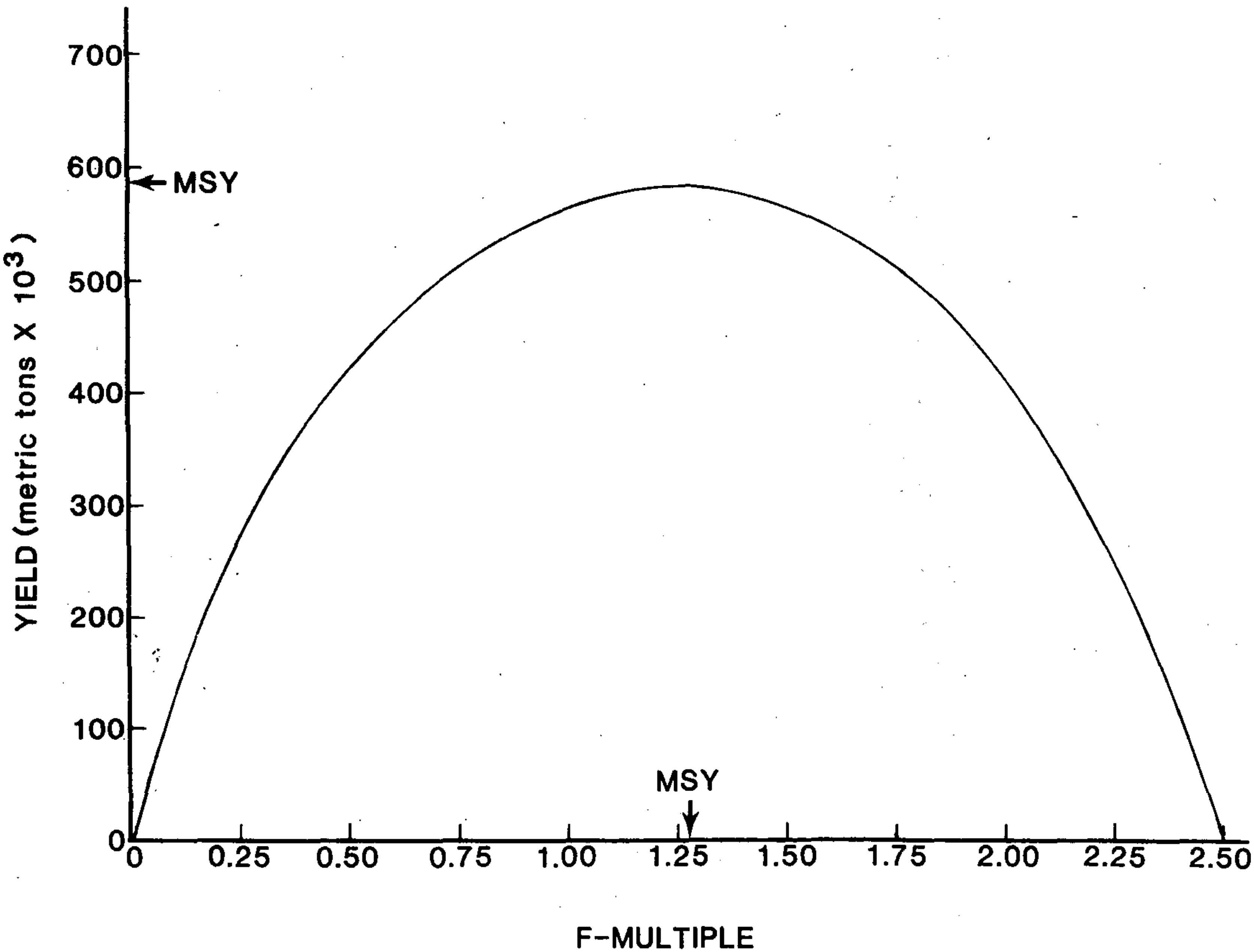
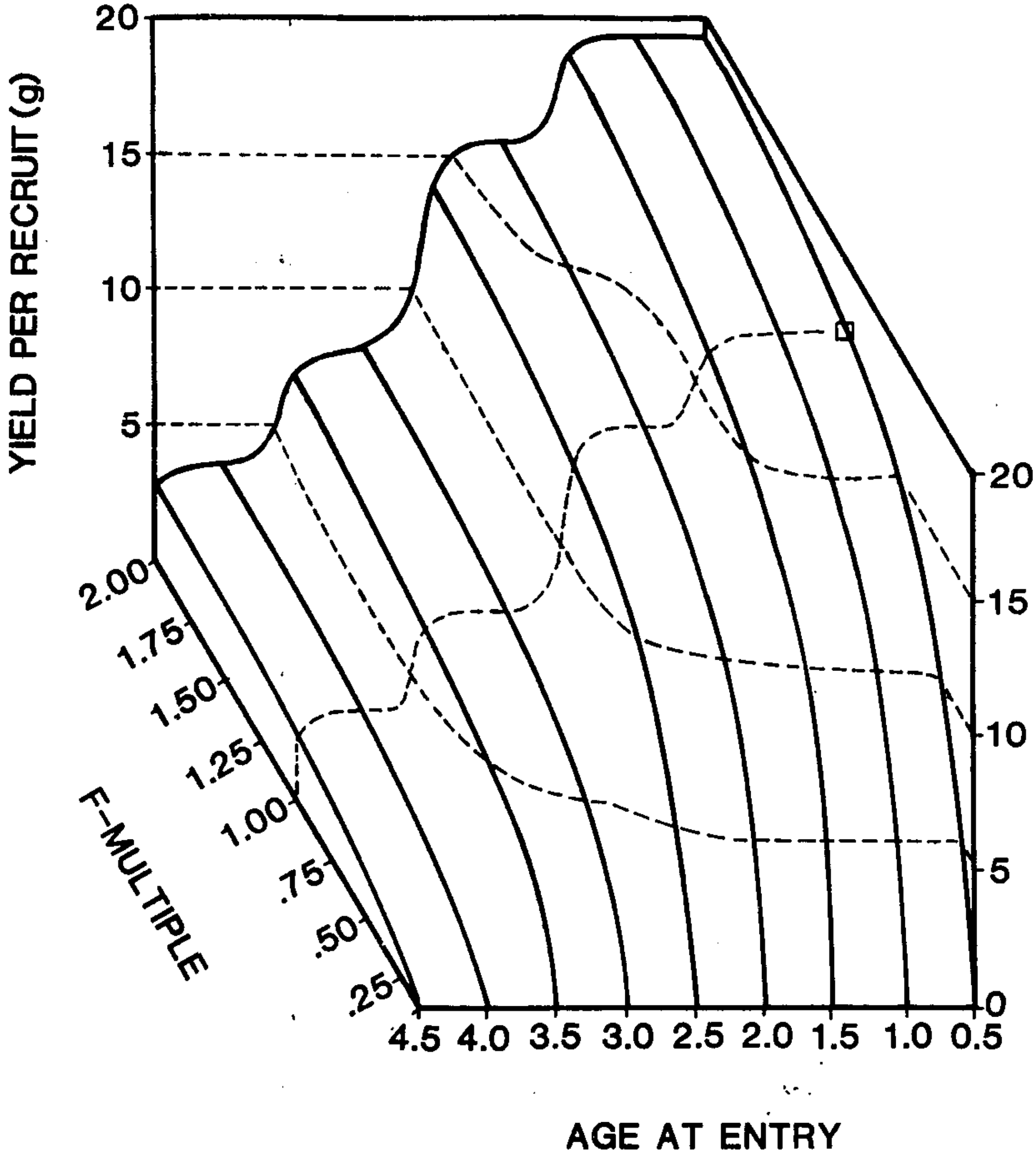


Figure 6. Sustainable yield predicted by a deterministic population simulation model of the Gulf menhaden fishery at multiples of the average fishing mortality (F-multiple = 1.00) for the 1964-1977 fishing season (Nelson and Ahrenholz 1986).



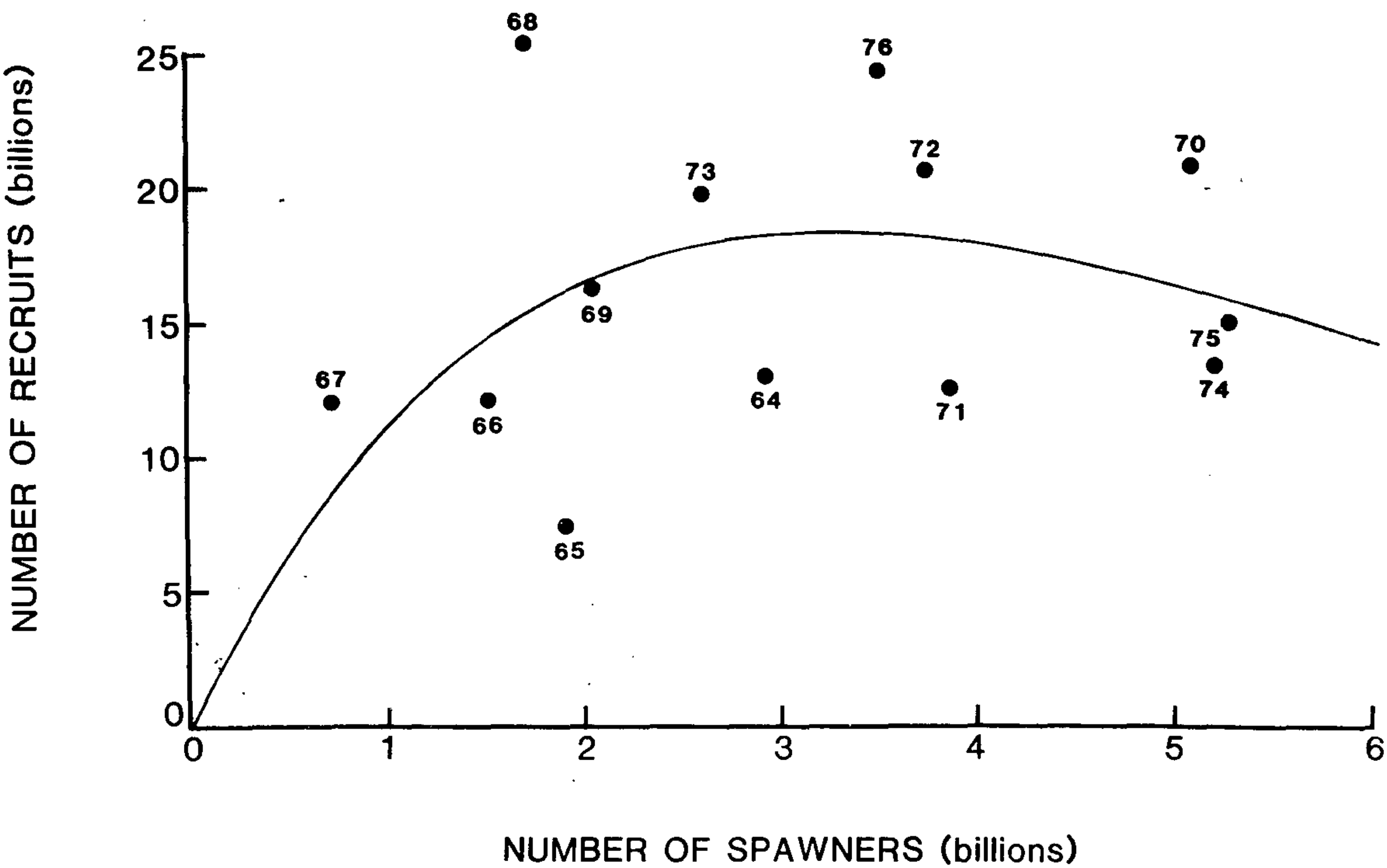
YIELD (metric tons X 10³)
700
600
500
400
300
200
100
0
MSY
MSY
0
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
F-MULTIPLE

Figure 7. Yield per recruit of Gulf menhaden under average conditions of growth and with multiples of average fishing mortality by 3-month interval (F-multiple = 1.00) for the 1964-1977 fishing seasons (average conditions indicated by ◻) (Nelson and Ahrenholz 1986).



YIELD PER RECRUIT (g)
20
15
10
5
F–MULTIPLE
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
AGE AT ENTRY
20
15
10
5
0

Figure 8. Ricker spawner-recruit relationship for number of spawners and recruits at age 1 of Gulf menhaden estimated as of January 1, for the 1964-1976 Gulf menhaden year classes ($R = S \exp (8.83 - S)/3.22$) (Nelson and Ahrenholz 1986).



NUMBER OF RECRUITS (billions)
0
5
10
15
20
25
NUMBER OF SPAWNERS (billions)
0
1
2
3
4
5
6
67
66
65
68
69
73
64
76
72
71
70
75
74