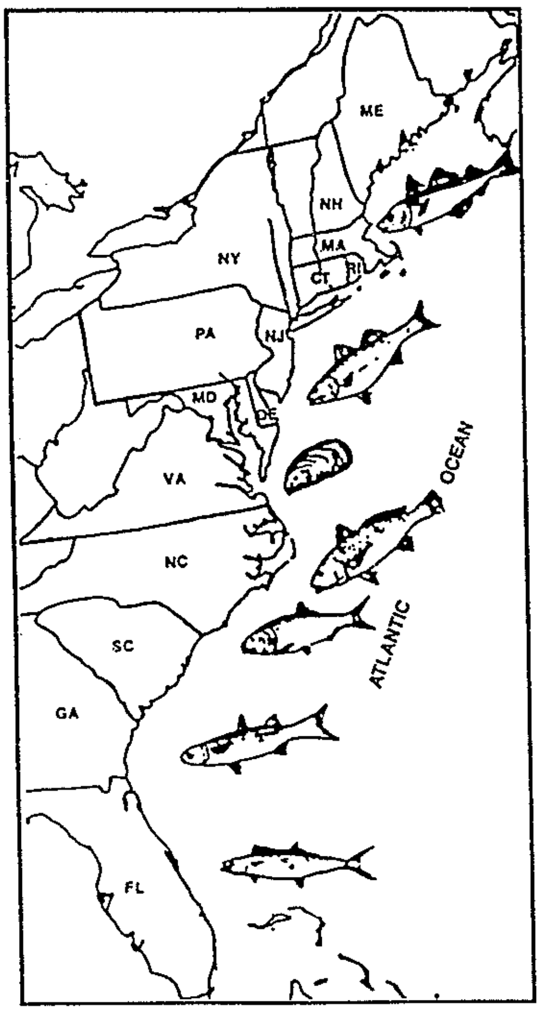
Fisheries Management Report No. 20 of the ATLANTIC STATES MARINE FISHERIES COMMISSION



WEAKFISH FISHERY MANAGEMENT PLAN AMENDMENT #1

March 1992

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Atlantic States Marine Fisheries Commission
Weakfish Fishery Management Plan
Amendment No. 1

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This Amendment was prepared in cooperation with the ASMFC Weakfish Management Board and Scientific and Statistical Committee and the Mid-Atlantic Fishery Management Council Coastal Migratory Committee.

October 1991

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EXECUTIVE SUMMARY

The Atlantic States Marine Fisheries Commission (ASMFC) adopted a management plan for the Atlantic coast weakfish fisheries in 1985. Due to a recent decline in weakfish catches coupled with the lack of implementation of the 1985 plan (which requested moderate conservation measures for weakfish), the ASMFC Policy Board recommended that a major amendment to the plan be developed. The Weakfish Scientific and Statistical Committee and Management Board have determined that the weakfish stock is overfished and recommended management measures to restore the stock over a ten year planning horizon.

A biological reference point of F_{20} was adopted as the target fishing mortality rate necessary for long term stock maintenance. F_{20} is that fishing mortality rate that results in a Maximum Spawning Potential (MSP) of 20% at equilibrium. This level of relative spawning stock biomass (i.e., weight of mature females in the stock) is believed to be the minimum level necessary to insure long term stock replacement. If fishing rates exceed these target levels, the chance of recruitment failure and stock collapse increases. The long term goal of this amendment is to reduce fishing mortality on the weakfish stock to F=0.34 (F_{20}).

Current estimates of fishing mortality (F) exceed 0.9 (about 52% of the stock is harvested annually by the commercial and recreational fisheries). The current fishing mortality rate represents an increase from an average F (on age 2+ fish) of 0.7 for the years 1982-87. Based on the estimates of current fishing mortality, the ASMFC recommended that the number of weakfish currently killed annually by fishermen should be reduced by 52%.

The Weakfish Management Board considered numerous options to reduce exploitation in the weakfish fisheries. The ASMFC recommended that states be given flexibility in achieving reductions in exploitation by using a combination of minimum size limits (with appropriate mesh regulations by gear), season and area closures for the commercial fisheries, size/bag limits for the recreational fisheries, and bycatch mortality reduction in non-directed fisheries (principally the South Atlantic shrimp fisheries, NC-FL). Reductions in exploitation will occur in three steps such that in year four (1995) management regulations will be adjusted to reach the target fishing mortality rate (F=0.34).

MANAGEMENT RECOMMENDATIONS

The following management measures required to achieve the objective of this amendment were unanimously adopted by the Policy Board and full Commission at the 50th Annual Meeting of the Atlantic States Marine fisheries Commission, Baltimore, MD :

1. That each State with directed weakfish fisheries (MA-NC and FL) implement a control strategy to achieve up to a 25% reduction but not less than a 15% reduction in annual exploitation in 1992.

2. That the minimum size limits for the possession of weakfish be:

   10 inches total length or greater in 1992
   11 inches total length or greater in 1993
   12 inches total length or greater in 1994.

3. That all States with directed weakfish fisheries (MA-NC and FL) implement a harvest control strategy to reduce annual exploitation by 25% in 1993 and continue this reduction in exploitation through 1994.

4. That in year four (1995) of the management program and thereafter, all States with directed weakfish fisheries (MA-NC and FL) implement a control strategy such that F does not exceed 0.34 (F_{20}).

5. That each State with directed weakfish fisheries (MA-NC and FL) annually prepare and submit a plan to achieve the control recommendations in this amendment to ASMFC's Weakfish Technical Committee (by June 1). Before July 31st of each year, the Weakfish Board will review and notify each state whether or not its plan was in compliance with the Weakfish Plan.

6. That South Atlantic States (NC-FL) implement programs to reduce the bycatch mortality of weakfish in their shrimp trawl fisheries by 50% by January 1, 1994. By June 1, 1993, a plan will be submitted by each state (NC-FL) to ASMFC's Weakfish Technical Committee outlining their strategy for implementation.

7. That the Mid-Atlantic Fishery Management Council move as soon as possible to implement complementary management measures for weakfish in the Exclusive Economic Zone (3-200 miles from the U.S. Atlantic Coast)

8. In the core commercial harvest area for weakfish (territorial waters of NJ-NC and in the EEZ offshore thereof), appropriate mesh size restrictions in gill nets and finfish trawl nets will be implemented at appropriate times and in appropriate areas to achieve a 75% escapement rate of that state's minimum size weakfish. This management strategy shall not apply to any other gear, e.g. pound net, haul seines, or shrimp trawls.

1.0 INTRODUCTION

Weakfish, (Cynoscion regalis) have supported fisheries along the Atlantic coast of the United States since at least the 1800's. The species is distributed from Maine to Florida and undergoes extensive seasonal migrations, moving north in spring and summer and south in fall and winter. They frequent shallow coastal and estuarine waters where they are highly sought after by both commercial and recreational fishermen. The migratory nature and importance of the species led to the development of a coastwide management plan for weakfish by the Atlantic States Marine Fisheries Commission (ASMFC) in 1985 (Mercer 1985).

The goal of the 1985 plan was to perpetuate the weakfish resource in fishable abundance throughout it's range and generate the greatest economic and social benefits from it's commercial harvest and utilization over time. The plan recommended that northern states (Rhode Island to Virginia) delay harvest of weakfish to ages greater than one, and that the use of trawl efficiency devices be promoted in South Atlantic shrimp fisheries to reduce bycatch mortality. Due to a lack of understanding of stock structure and geographical variation in key life history parameters, no consensus was reached concerning appropriate biological reference points.

Instead, ASMFC recommended that a comprehensive stock identification study be conducted to determine the degree of stock separation and the extent of mixing. Additional research was recommended to determine catch and effort in important fisheries including size/age composition of the landings, develop an index of recruitment, and define the reproductive biology of weakfish.

In 1990, the ASMFC Weakfish Plan Review Team reviewed the status of the stock and evaluated the effectiveness of the Plan in accomplishing it's goals and objectives. The consensus of the review team was that the goal and objectives of the plan were valid but since full implementation of the plan did not occur, it's effectiveness in protection of the Atlantic weakfish stock was considered minimal. The group recommended that a major amendment to the 1985 plan be developed jointly with the Mid-Atlantic Fishery Management Council. The ASMFC Policy board accepted this recommendation at the 1990 Annual meeting and directed the ASMFC Advisory Committee to reconvene the Weakfish Scientific and Statistical Committee and Management Board to develop Amendment No. 1 to the weakfish management plan.

2.0 STATUS OF THE STOCK

The Scientific and Statistical (S&S) Committee was formed during January 1991 (Appendix I) and met periodically to evaluate the status of the Atlantic weakfish stock and to formulate stock rebuilding strategies. Vaughan et al. (1991) presented results of the most recent analytical assessment of the weakfish population along the Atlantic coast. The analysis assumed a single unit stock based on results of recent stock identification studies (Scoles 1990; Graves et al. 1991). Both studies suggested that the Atlantic Coast weakfish fisheries should be managed as a single, large interdependent unit.

Commercial and recreational landings (USDC 1991) and unpublished size/age composition data were used to construct a catch at age matrix for fishing years 1982-1987 which served as input to virtual population analyses (VPA). Vaughan et al. (1991) also examined the potential effect on yield and reproductive potential of bycatch of predominantly age 0 weakfish in non-directed fisheries.

Results of virtual population analyses indicated that F (instantaneous fishing mortality rate) for fully recruited age groups (ages 2 and older) averaged 0.7 for fishing years 1982-1987 (Vaughan et al. 1991). An index of maximum spawning potential (%MSP) was calculated as the ratio of spawning stock size calculated when fishing mortality rate is equal to that observed (estimated from VPA) divided by the spawning stock size calculated when F=0 (unfished spawning stock). Assuming a natural mortality rate of 0.3 and no other sources of mortality, (i.e. shrimp fishery bycatch),the current estimate of MSP was found to be equal to 12%. Incorporating estimates of mortality of young weakfish killed in the South Atlantic shrimp trawl fisheries into the analysis yielded an MSP value of 7%. Values of 7-12 % are considered low, and are indicative of reduced spawning stock biomass due to recruitment overfishing.

The S&S Committee reviewed the assessment and recommended that a Stock Assessment Subcommittee be formed to refine and update estimates of current F and to develop biological reference points and stock rebuilding strategies. An inherent weakness in VPA and other cohort based analyses is that the estimates of age specific fishing mortality rates are most reliable for the oldest cohorts and become progressively less robust for the youngest age groups in the analysis (Megrey 1989). As a result, the S&S recommended that alternative methods of estimating current mortality be employed including catch curve and other length based analyses (see Appendix II).

Results of these analyses indicate that the Atlantic weakfish stock is currently experiencing fishing mortality rates of 0.9 or greater (an increase from an average F of 0.7 during the mid-

1980's). Current levels of fishing result in an annual exploitation rate of 52% (this is the percentage of the fish which die annually due to fishing). These high levels of exploitation have resulted in the erosion of spawning stock biomass as evidenced by the compression in size/age composition of weakfish taken in both the recreational and commercial fisheries since the mid-1980's (Vaughan et al.1991). The S&S committee concluded that current rates of fishing are too high for long term stock maintenance and recommended immediate remedial action be taken to reduce exploitation rates within the fisheries.

3.0 BIOLOGICAL REFERENCE POINTS

A major deficiency of the 1985 plan developed by ASMFC is than the problem of overfishing was not specifically addressed. The FMP Review Team recognized this problem and recommended that Amendment 1 to the Weakfish FMP be developed jointly with the Mid-Atlantic Fishery Management Council. Fishery management plans developed under federal authority must comply with the seven national standards as defined in the Magnuson Fishery Conservation and Management Act (MFCMA). FMP's developed by the ASMFC are not subject to this requirement, however, the S&S committee recommended that this amendment be developed in compliance with the national standards to expedite development of compatible management measures for federal waters.

National Standard No.1 requires that "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery". Overfishing was later defined as "the level or rate of fishing mortality that jeopardizes the long-term capacity of a stock to produce MSY on a continuing basis" (NMFS 602 Guidelines For Fishery Management Plans). Effective February 25, 1991 all new and existing FMP's developed under the MFMCA must contain a measurable definition of overfishing which focuses on recruitment and the long-term reproductive capacity of the stock.

The weakfish S&S committee and Management Board defined overfishing for weakfish as the level of fishing that will, if maintained, reduce the spawning stock biomass below 20% of the spawning stock biomass at F=0 (a rate of fishing herein referred to as F_{20}). This level of spawning stock biomass is believed to be the minimum level necessary to insure long term stock replacement (Gabriel et al. 1989). If fishing mortality rates exceed this level, the chance of recruitment failure and stock collapse increases. F_{20} was the most liberal biological reference point considered, being less conservative than F_{30}, F_{max}, and $F_{0.1}$, which also were evaluated by the S&S Committee. F_{20} was calculated to be an instantaneous fishing mortality rate (F) equal to 0.34. Since current F is 0.9 or greater (see Appendix II), a reduction in annual exploitation of 52% is required to reach the target F of 0.34 (assuming current levels of shrimp fishery bycatch).

4.0 DESCRIPTION OF THE FISHÉRIES

4.1 Commercial Fisheries

Mercer (1985) gives an historical overview of the commercial fisheries for weakfish. The principal fisheries occur seasonally along the Atlantic coast following the species north-south and inshore-offshore migratory behavior. Commercial weakfish landings have fluctuated from a peak of 42 million pounds in 1945 to a low of 3.0 million pounds in 1967. Following this record low year, total commercial landings increased more or less continuously to 35.9 million pounds in 1980. Landings declined to less than 20 million pounds by 1982 and varied without trend about this level until 1988 (Table 1). Commercial landings declined by 50% from 20.5 million pounds in 1988 to 9.9 million pounds in 1990. Landings in 1990 declined by 73% compared to 1980 and represented only 50% of the average landings for the period 1980-1990 (Figure 1).

The Weakfish Management Board instructed the S&S committee to characterize the fisheries for weakfish for the years 1987-89 and use landings during this period as the reference level to formulate harvest reduction strategies. During the period 1987-89, 51.7 million pounds of weakfish were reported taken in the commercial fisheries along the Atlantic coast (NMFS General Canvas data). Of this total, 60.8% was reported taken in waters under state jurisdiction, the balance taken in the EEZ (39.2%). The principal gears used to harvest weakfish were gill nets and otter trawls (together they accounted for over 85% of the total catch), followed by pound nets and haul seines (Fig. 2).

The majority of the commercial landings occur during the fall and winter months as weakfish emigrate from mid-Atlantic estuaries to their overwintering grounds in the South Atlantic region. During the winter, sink gill nets and otter trawls contribute about equally to the catch, while otter trawls predominate in the fall fishery (Fig. 3). Gill nets, pound nets and seines are the principal gears used during the summer when weakfish reside in shallow coastal and estuarine waters. The mortality rate of weakfish discarded from these fisheries (ie., sublegal fish) is expected to be very high.

Weakfish landings (1987-89) by state by month (expressed as percent of total commercial landings) are given in Table 2. North Carolina landed 71.8% of the total, followed by New Jersey (11.4%), Virginia (8.6%), Maryland (3.8%), Delaware (3.1%),and New York (1.1%) (Figure 4). Landings reported for the New England states (Connecticut, Rhode Island and Massachusetts) accounted for less than 0.2% of the total. Approximately half of the Atlantic coast total occurred off North Carolina from January through March.

4.2 Recreational Fisheries

Weakfish are an important component of the recreational fisheries along the Atlantic Coast. They are taken by a variety of angling techniques including live bait fishing, jigging, trolling and chumming primarily during the warmer months of the year (Mercer 1985). Recreational catch statistics for weakfish are estimated from the Marine Recreational Fishery Statistics Survey conducted by the NMFS since 1980 (Table 1). Three catch types are defined: Type A refers to catches that are available for identification and measurements; Type B1 are fish caught and kept but not available for measurement or released dead; and Type B2 are fish released alive.

During the period 1981-1990, the majority of weakfish were taken from boats (although the catch from shore can be substantial during certain parts of the fishing season, primarily during the fall migration) (Figure 5). Most of the recreational harvest during this period occurred in the Middle Atlantic region (Virginia through New Jersey) with minor contributions from the North and South Atlantic region (Vaughan et al. 1991).

Recreational landings (Type A+B1) declined from a high of 42.6 million pounds in 1980, to an average of 10.2 million pounds between 1981-1988, and then to 2.5 million pounds in 1989. Recreational landings declined further to 1.5 million pounds in 1990 (Figure 1). Weakfish catch in numbers were more variable with generally small contributions from Type B2 caught fish. Total recreational catch in numbers (Type A+B1+B2) declined from 14.8 million weakfish in 1980 to 2.3 million in 1982, rose to 12.3 million in 1986, and then declined to less than 2.0 million fish in 1989 and 1990.

The high recreational landings during 1980 were comprised largely of age-2 weakfish from the 1978 year class (Vaughan et al. 1991). The large decline in landings during the early 1980's is most likely due to the lack of any strong year classes since 1978. With the gradual disappearance of this year class, the mean weight of Type A weakfish declined from about 3.5 pounds in 1982 to 1.1 pounds in 1990. The combination of poor to mediocre recruitment and relatively high exploitation rates during the mid-1980's resulted in truncation of the size/age composition of the stock as evidenced by the length frequency distributions of weakfish taken in the recreational fishery (Figure 6).

5.0 Institutional Requirements

5.1 Weakfish Technical Committee and Management Board

This amendment calls for reductions in fishing mortality on weakfish and allows States flexibility to achieve recommended reductions. Implementation of Amendment 1 will be an interactive program among State management agencies, the Mid-Atlantic Fishery Management Council, and the ASMFC that will take at least two years to fully complete. The ASMFC Interstate Fishery Management Program (ISFMP) Policy Board will appoint groups as necessary to implement this amendment. The ISFMP Policy Board created the following institutional provisions in October 1991 for the implementation of Amendment No. 1 to the 1985 FMP:

1. The ASMFC Weakfish Management Board will continue in existence and be expanded to include all States with an interest in managing weakfish. The Board will make management decisions germane to implementation of Amendment 1. Board findings and decisions will be reported to ASMFC's Interstate Fisheries Management Program Policy Board which will have final authority for judging non-compliance with Amendment 1 recommendations.

2. ASMFC's Weakfish Technical Committee will be maintained to collect data and conduct analyses as necessary for the implementation and monitoring of this Amendment. The Technical Committee will be comprised of fisheries scientists from States that declare an interest in managing weakfish, and staff from the ASMFC, Mid-Atlantic Fishery Management Council and National Marine Fisheries Service.

5.2 Annual Monitoring Program

In order to assess the status of the weakfish stock and to monitor the effectiveness of management efforts, the following data should be collected annually and reported to the Weakfish Technical Committee by June 1st of each year:

I. Fisheries-Dependent Data

A. Commercial

1. NMFS General Canvas Data

Harvest and length-frequency by gear (MA through FL). Commercial gears should include: trawls, gill nets, pound nets, and haul seines.

2. State Landings

Landings data from state records by season and gear (MA through FL). Length frequency of the harvest and sub-legal discards should be provided. Seasonal breakdown should be monthly, at a minimum, or daily/weekly for those states proposing seasonal closures less than one contiguous month as a means of meeting target exploitation reductions.

B. Recreational

1. NMFS MRFSS Data

NMFS recreational survey data (A, B1 and B2) by region and state where data permit (MA through FL). Reporting should include catch by wave, length frequency and other data from the intercept survey component.

2. State Recreational Surveys

Independent state recreational survey data should be provided if available. It would be desirable if data included estimates of total catch and harvest, and length frequencies of harvest and sub-legal discards.

II. Fisheries-Independent Data

A. Juvenile Recruitment Data

1. NMFS Fall Trawl Survey

NMFS Northeast Fisheries Center fall trawl survey data on weakfish abundance, length frequency, age frequency and other biological characterization data (e.g. sex ratio, maturity). Data resolution by station and strata.

2. State Surveys

State survey data that provide measure of juvenile relative or absolute abundance and length-frequency of catch (DE,NJ,MD,VA,NC). Survey sampling protocol should be characterized (e.g., gear size/type, set time, location and dates).

B. Adult Stock Structure Data

1. Spawning Stock

Adult stock characterization data from state survey sampling programs (DE,NJ,VA,NC). Characterization by length frequency, at a minimum, and by age/sex frequency if available.

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Table 1. Commercial and recreational weakfish landings (thousands of pounds) along the Atlantic Coast of the U.S., 1980-1990.

Year	Commercial(%)	Recreational(%)	Total
1980	35,963 (45.7)	42,632 (54.3)	78,595
1981	26,376 (61.6)	16,411 (38.4)	42,787
1982	19,255 (69.1)	8,619 (30.9)	27,874
1983	17,543 (58.6)	12,396 (41.4)	29,939
1984	19,726 (72.1)	7,626 (27.8)	27,352
1985	16,400 (64.0)	9,210 (36.0)	25,610
1986	20,206 (64.1)	11,302 (35.8)	31,511
1987	17,927 (68.4)	8,298 (31.6)	26,225
1988	20,534 (71.9)	8,015 (28.1)	28,549
1989	14,187 (85.1)	2,489 (14.9)	16,676
1990	9,880 (86.8)	1,499 (13.2)	11,379
Average	18,203	8,586	26,789

Source: Fisheries of the U.S., 1981-1991 and MRFSS.

Table 2. Atlantic coast commercial landings of weakfish (1987-89) by state by month expressed as percent of total coastwide landings.

	NC	VA	MD	DE	NJ	NY	NE	TOT
JAN	16.81	0.11	0.00	0.00	0.00	0.01	0.01	16.94
FEB	16.20	0.04	0.00	0.00	0.00	0.00	0.01	16.25
MAR	12.32	0.10	0.00	0.00	0.00	0.00	0.00	12.42
APR	5.24	0.68	0.14	0.31	0.13	0.02	0.00	6.52
MAY	1.42	1.21	0.08	1.28	1.87	0.35	0.01	6.22
JUN	0.78	0.96	0.14	0.92	0.44	0.23	0.01	3.48
JUL	1.02	0.49	0.14	0.15	0.23	0.14	0.04	2.21
AUG	1.99	0.88	0.20	0.21	0.71	0.09	0.03	4.11
SEP	2.47	0.90	0.41	0.16	1.44	0.11	0.03	5.52
OCT	2.58	1.19	1.87	0.06	4.49	0.07	0.03	10.29
NOV	2.89	1.67	0.73	0.00	2.05	0.03	0.01	7.38
DEC	8.03	0.40	0.04	0.00	0.03	0.01	0.01	8.52
TOT	71.75	8.63	3.75	3.09	11.39	1.06	0.19	99.86

Source: Unpublished NMFS General Canvas Data

Figure 1. Commercial and recreational landings of weakfish along the Atlantic coast of the U.S., 1980-1990.

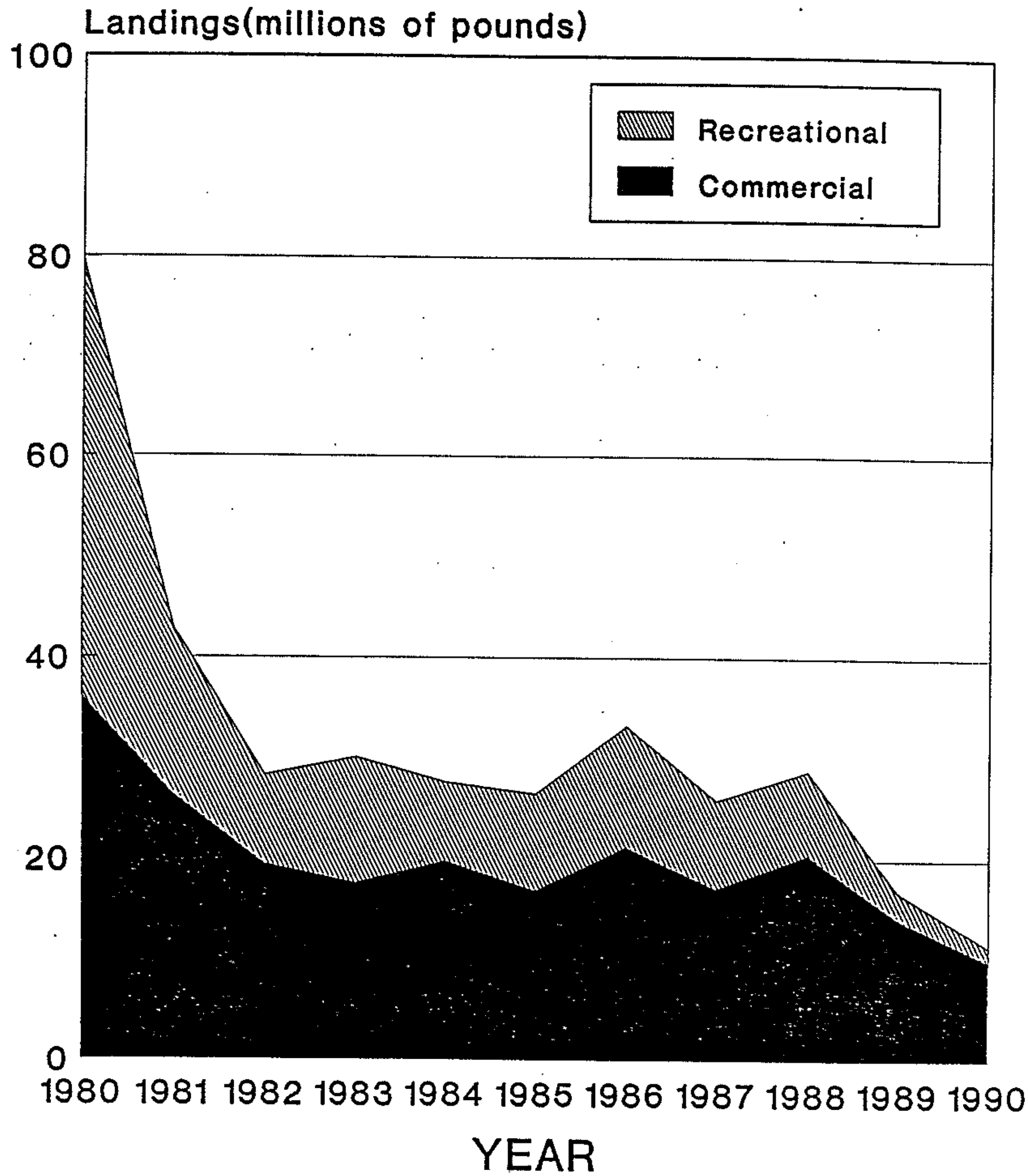


Figure 2. Commercial landings of weakfish along the Atlantic coast of the U.S. by gear type expressed as percent of total landings, 1987-1989.

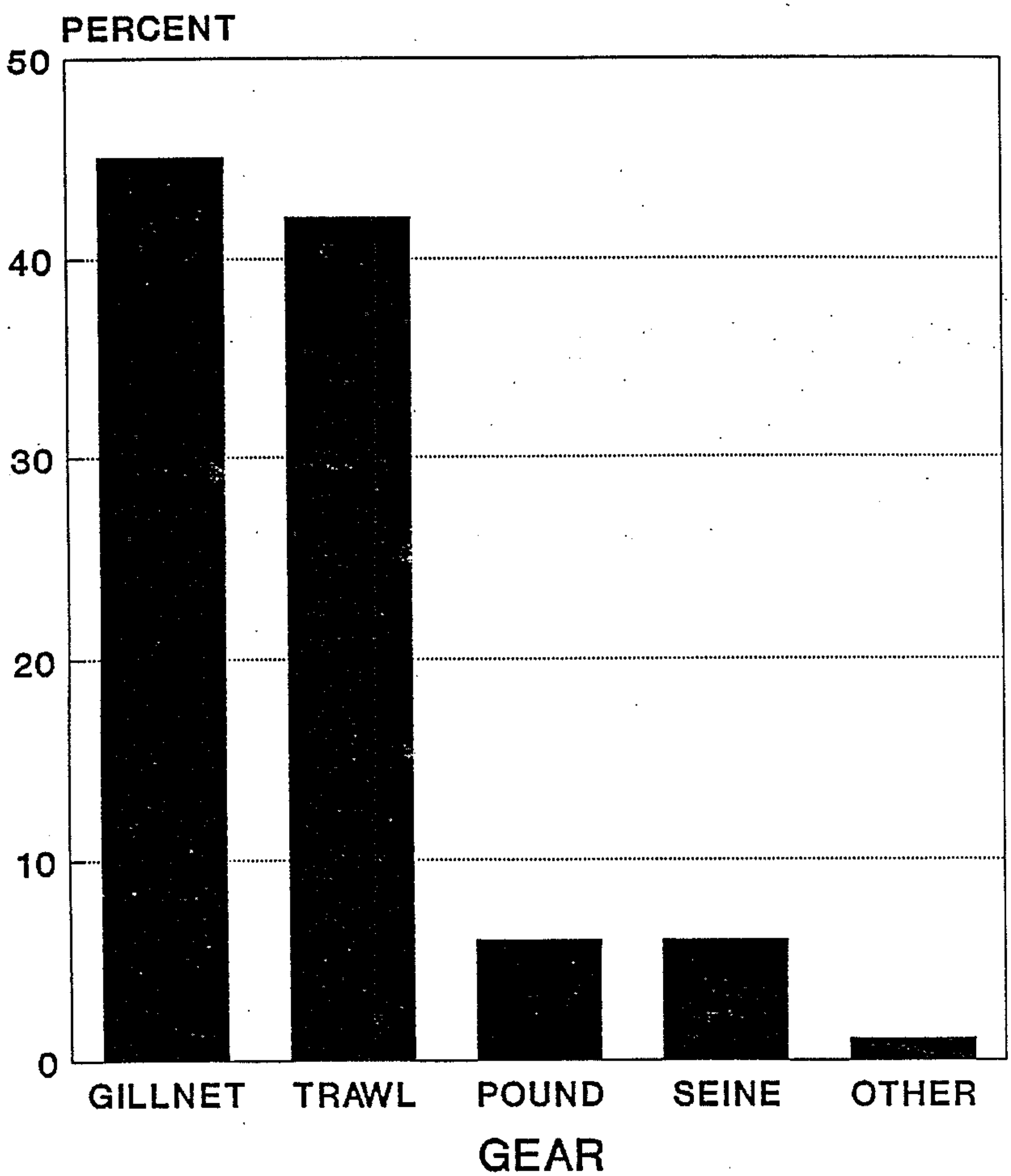


Figure 3. Commercial landings of weakfish along the Atlantic coast of the U.S. by gear type by month expressed as percent of total landings, 1987-1989.

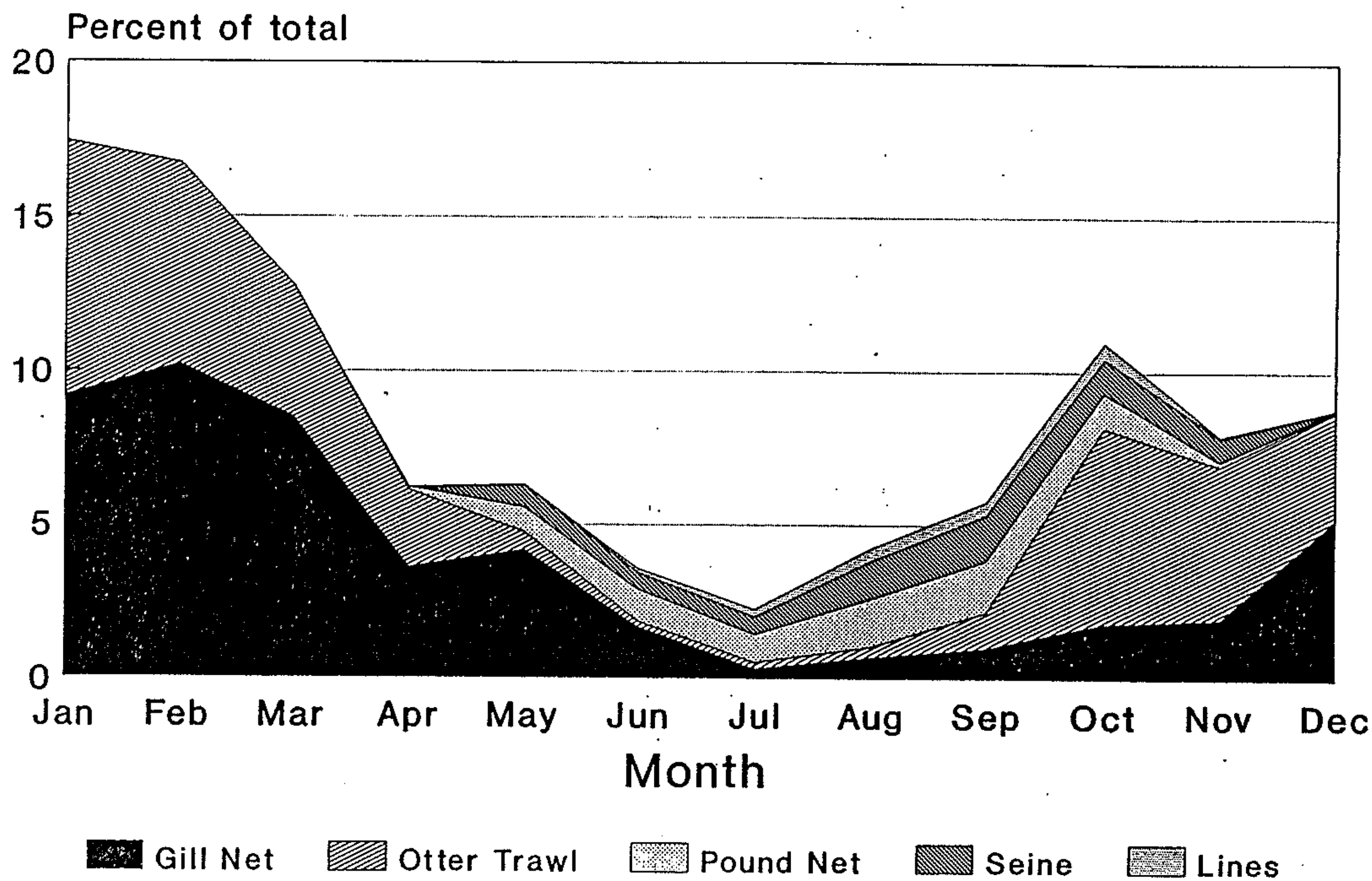


Figure 4. Commercial landings of weakfish along the Atlantic coast of the U.S. by state by gear type expressed as percent of total landings, 1987-1989.

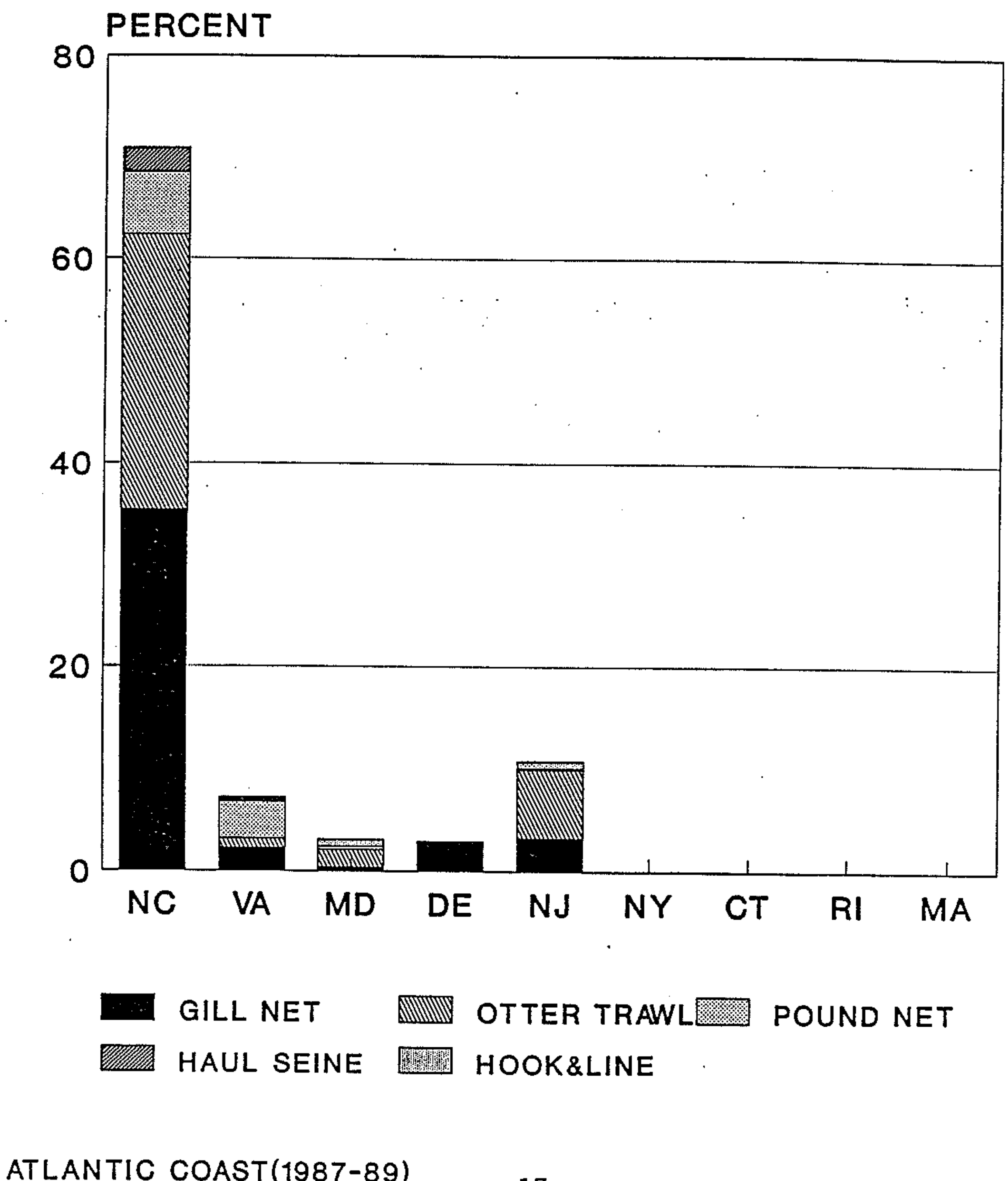
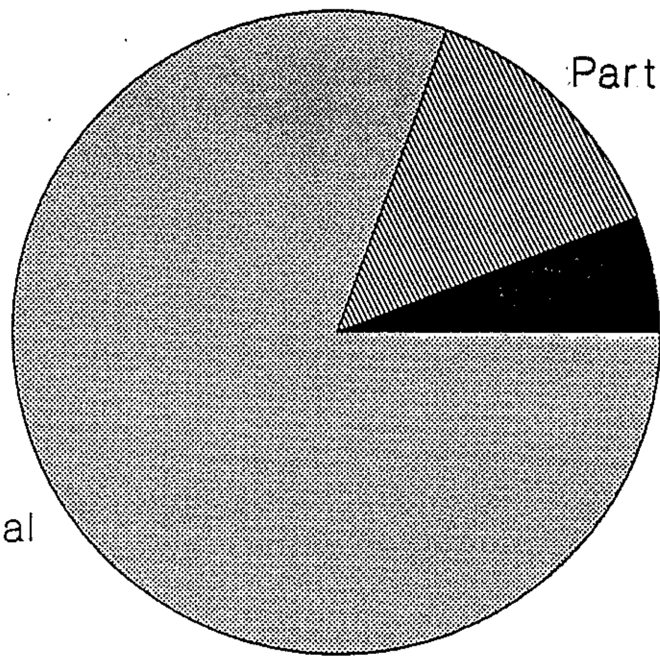
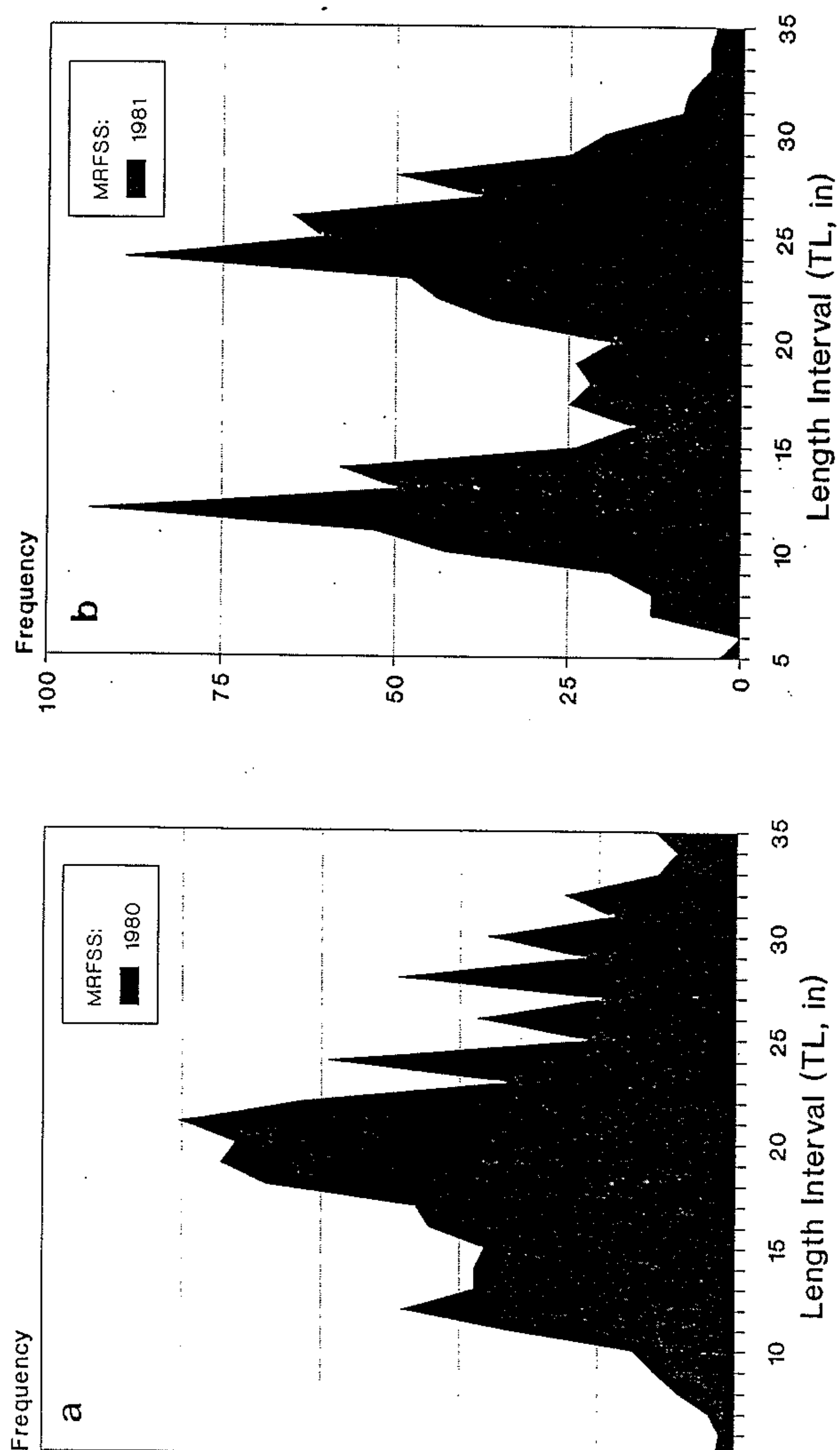


Figure 5. Recreational landings of weakfish along the Atlantic coast of the U.S. by mode expressed as percent of total weight landed (Type A+B1), 1981-1990.



1981-1990

Figure 6. Annual length frequency distributions for weakfish from the Atlantic coast recreational fishery, 1980-1990 (a-f).



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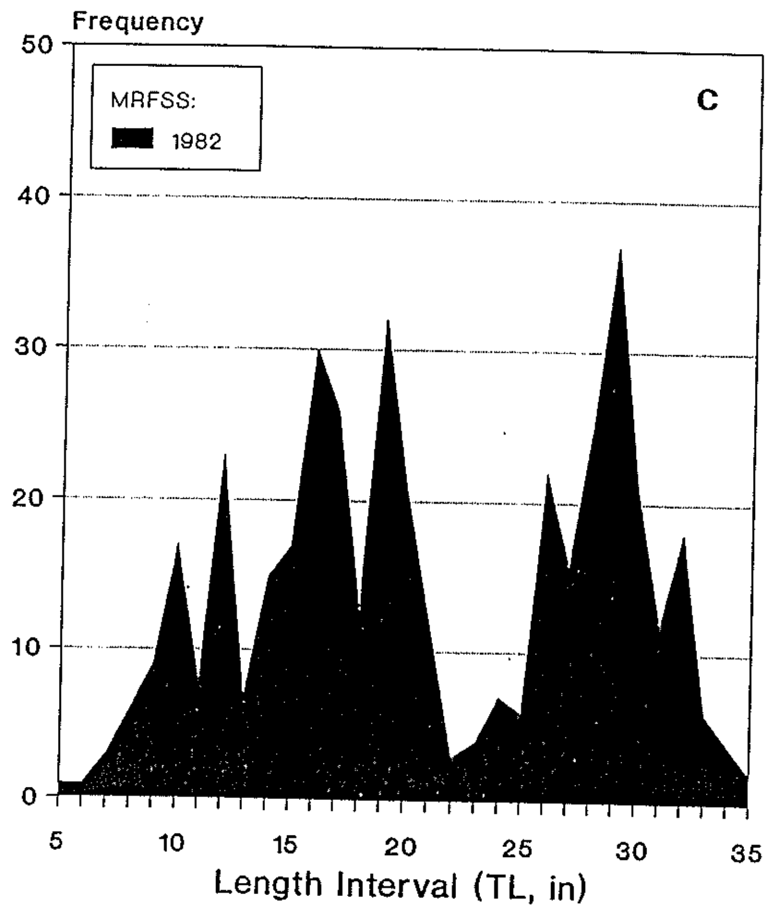
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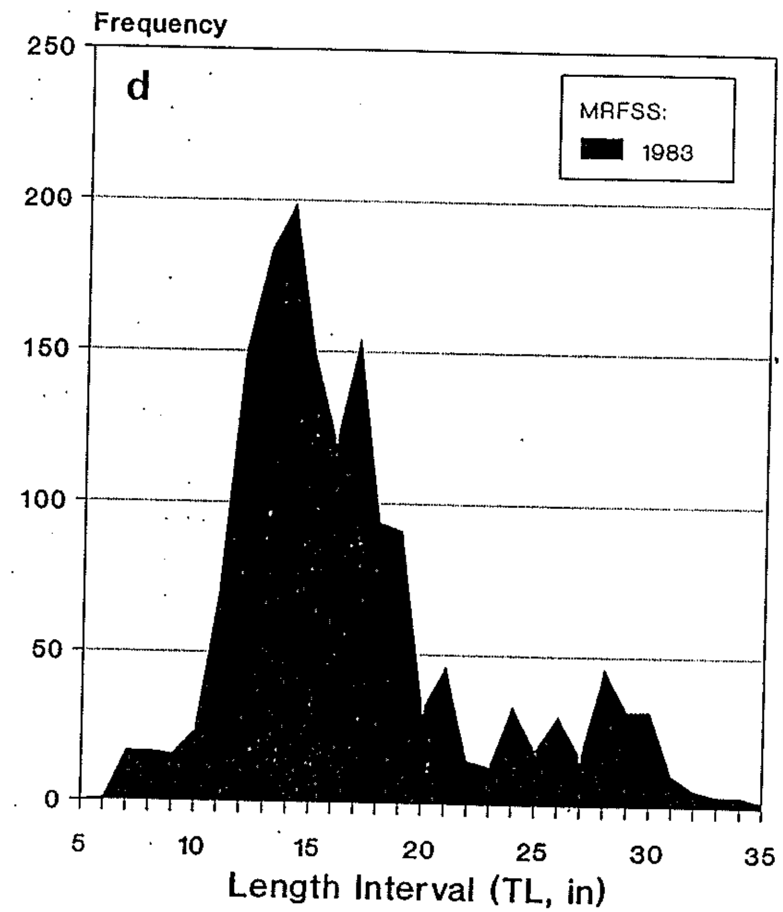
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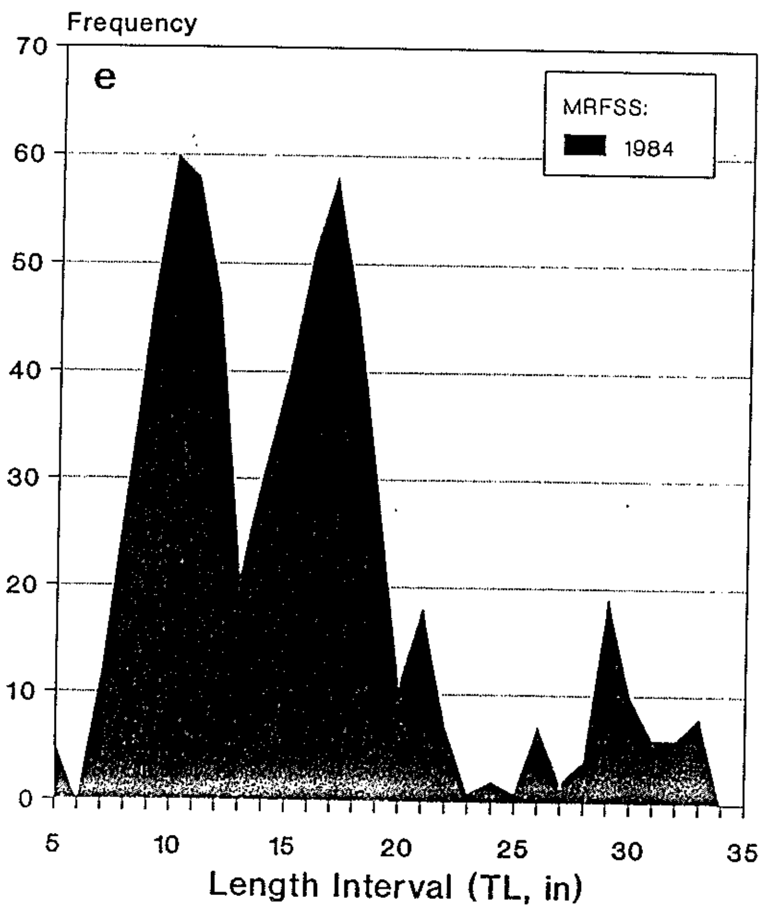
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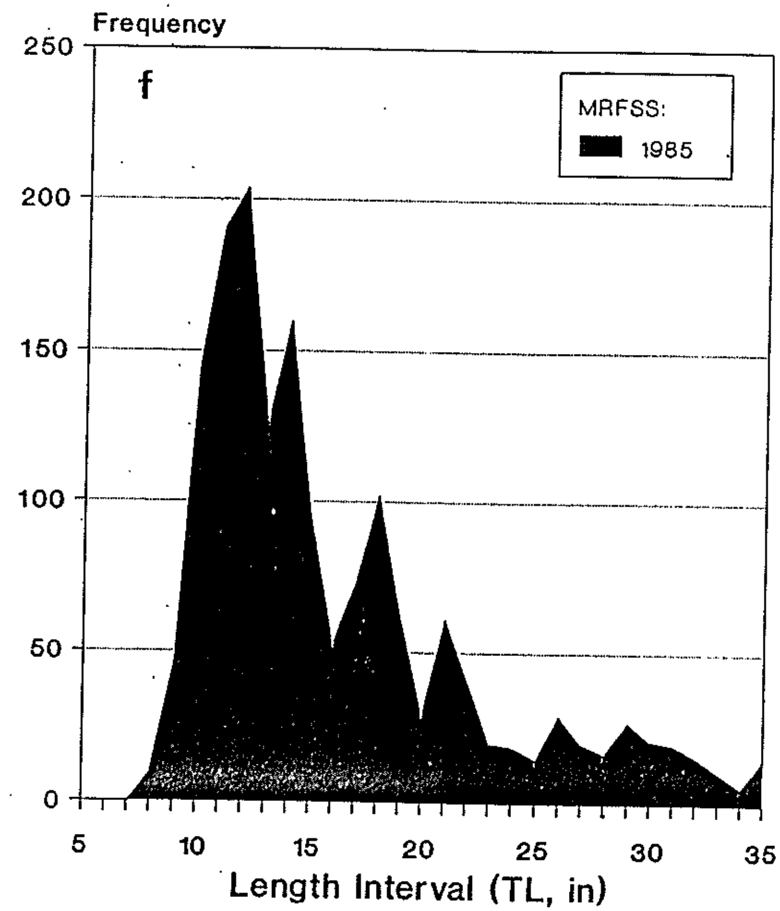
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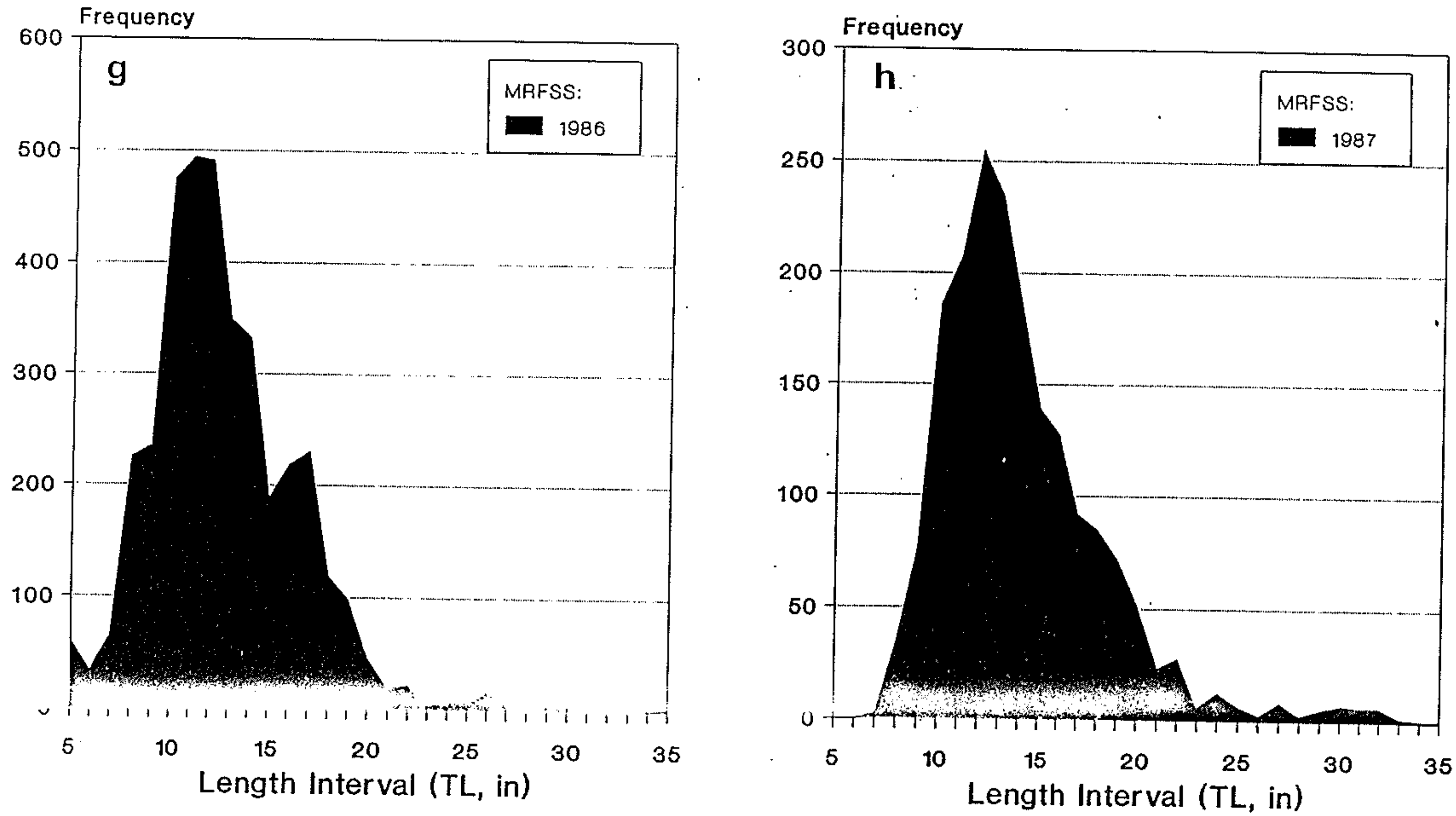
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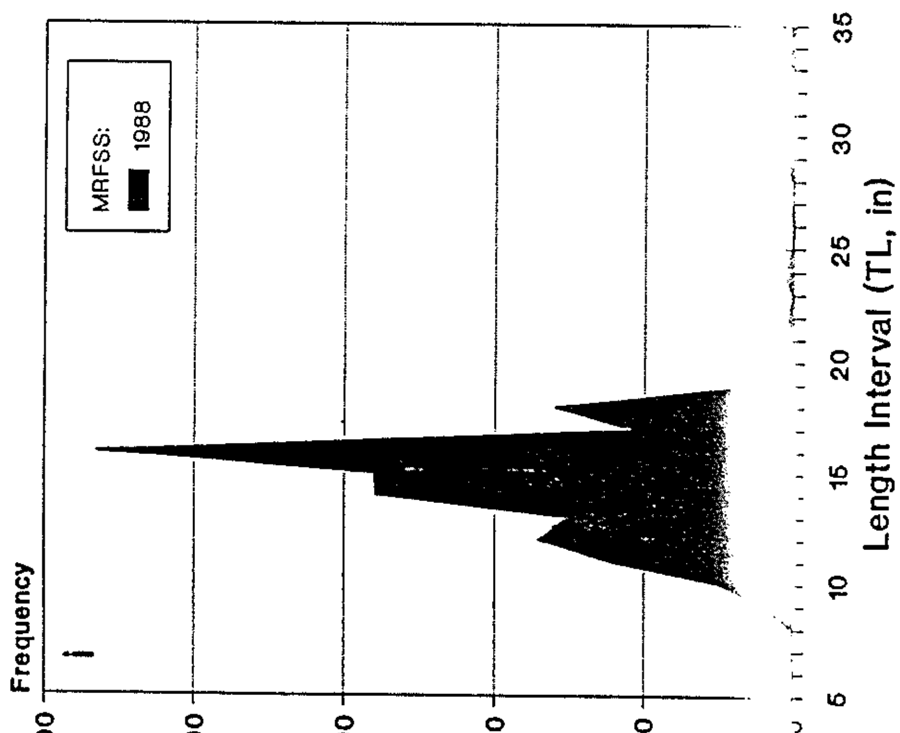

Frequency
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MRFSS:
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400
300
200
100
5
10
15
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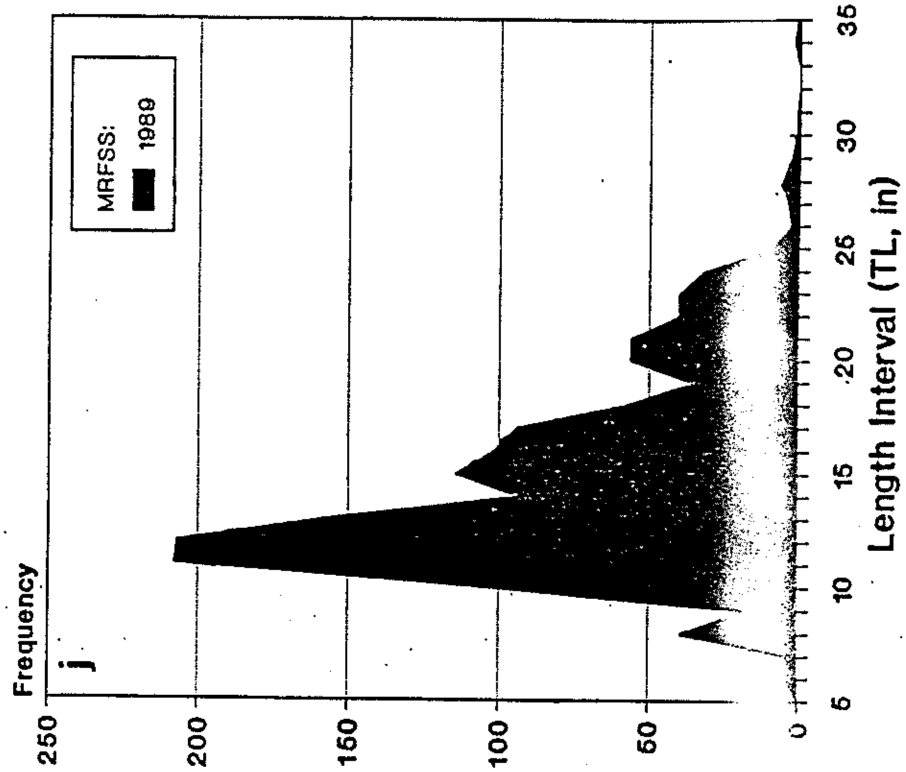
25
30
35
Length Interval (TL, in)



Frequency
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150
100
50
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5
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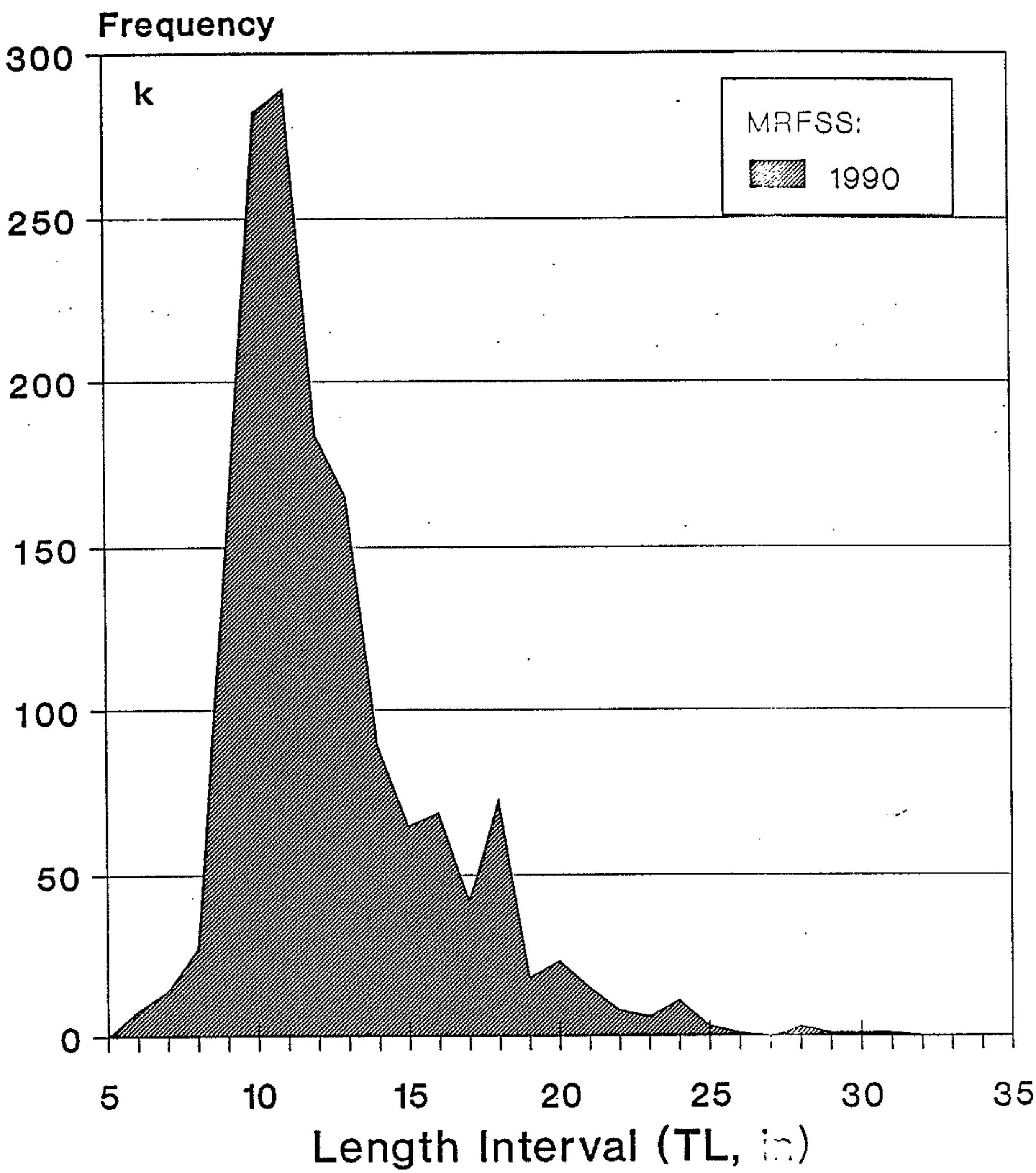
35
Length Interval (TL, in)


Frequency
k
MRFSS:
1990
300
250
200
150
100
50
0
5
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25
30
35
Length Interval (TL, in)

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Appendix II Report of the Weakfish Stock Assessment Subcommittee

Appendix II

WEAKFISH STOCK ASSESSMENT SUBCOMMITTEE REPORT TO ASMFC WEAKFISH SCIENTIFIC AND STATISTICAL COMMITTEE FOR AMENDMENT NO.1 TO THE WEAKFISH MANAGEMENT PLAN

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Introduction

This report summarizes the work conducted by the Weakfish Stock Assessment Subcommittee (SSC) during the development of Amendment 1 to the ASMFC Weakfish Management Plan. The primary charge of the SSC is to conduct analyses to evaluate the status of the stock and to develop appropriate stock rebuilding and management strategies. The topics considered by the SSC included:

1. Catch Curve Analysis
2. Length Based Estimates of Total Mortality (Z)
3. Age-Specific Natural Mortality
4. Incorporating Release Mortality
5. Level of Shrimp Bycatch Ratio
6. Biological Reference Points
7. Mesh Selectivity
8. Genmod Analysis
9. Recreational Bag/Size Limits
10. Exploitation Reductions-Size Limit/Bycatch Interaction

Topics 1 and 2 are to provide a current estimate of total mortality, which coupled with an estimate of natural mortality, provide an estimate of current fishing mortality. Topics 3, 4, and 5 address assumptions used in the models by Vaughan et al. 1991. They effect the magnitude of the level of fishing impacts and potential gains from different management measures. The biological reference point (topic 6) is necessary for determining whether the stock is overfished (definition of overfishing required by FCMA Section 602), what management measures may be needed, and later whether the desired results have been accomplished. Management measures (topics 7-10) also were discussed and a brief summary is provided.

1. Catch Curve Analysis

Catch at age vectors were estimated from the MRFSS data set (recreational fishery only) for calendar years 1982 through 1989 in the same manner that catches at age by cohort were developed by Vaughan et al.(1991). However, since no age-length keys were available for 1989, the mean age-length keys (early and late) for fishing years 1982-1987 were used. Application of catch curve analysis to calendar year data requires the assumption that constant recruitment and fishing mortality for those cohorts is represented in that calendar year. Estimates of Z and F (assuming M = 0.3) are presented in Table 1.

Because recreational anglers would be expected to selectively retain larger weakfish in preference to smaller weakfish, (especially in the mid Atlantic states where recreational fishing predominates), estimates of Z and F based solely on recreational statistics are likely to be low. A catch at age vector was developed for calendar year 1989 using both recreational and commercial data. Z was estimated as 1.24 (so F = 0.94 with M = 0.3), with SE = 0.15 and R^2 = 0.95. The subcommittee reached a consensus that current F is approximately 0.9 to 1.0.

2. Length Based Estimates of Total Mortality (Z)

In the absence of age frequency data, total instantaneous mortality rates (Z) can be estimated for any finfish species when length frequency data and von Bertalanffy growth parameters (K, L_∞) are available . Since von Bertalanffy parameter estimates are available for weakfish, several length frequency data sets were used to estimate Z for Atlantic coast weakfish with the expression derived by Hoenig (1987):

$$Z = \log e \left(\frac{\exp - K*(L-L_\infty) + (L_\infty - L_1),}{L-L_1} \right) \quad (1)$$

where: K and L_∞ are parameters of the von Bertalanffy growth model;

L_1 the length (inches,TL) at full recruitment to the gear or fishery;

L = the arithmetic mean or median length (L_{med} are estimated from L_1 to the end of the frequency distribution).

Since the median length is more robust than the arithmetic mean to extreme skewness in the descending limb of the length frequency distribution, the median length (L_{med}),in this case is probably a more reliable estimate of central tendency.

A time series of total mortality (Z) was derived from equation 1 based on three length frequency data sets :1) the 1979-1989 weakfish length frequencies for marine recreational fishermen based on the MRFSS; 2) the 1983-1989 length frequencies from the NEFC commercial trawl fishery; and 3) the 1982-1989 length frequencies from the North Carolina winter trawl fishery. Since the size-dependent predation (Mager and Sheperd; Anderson 1988; Beyer 1989).

Results of recent studies of North Sea fishes (Dekker 1983; Daan 1983; Sparholt 1990) revealed that predation rates on age 1+ cod, haddock, whiting, and Atlantic herring were highest among younger and smaller fish, and that size-dependent predation was the major factor influencing the inverse relationship between M and body size (age) for each species. The fact that smaller and younger fish within each North Sea species experienced higher predation mortality is consistent with the theoretical expectation (Dickie et al. 1987; Boudreau and Dickie 1989) that smaller body size renders fish more susceptible to smaller, more numerous and diverse vertebrate and invertebrate predators. Clearly it would be useful to determine whether age-specific M for weakfish might alter biological reference points ($F_{0.1}$, F_{20}) in the YPR model, or the vector of fishing mortalities from the VPA when M was assumed to be constant.

Lacking direct estimates of age-specific M, Boudreau and Dickie (1989) proposed that an inverse power regression based on several finfish species can be used to estimate size or age-specific M given weight at age data (W):

$$M = 2.88 * W^{-0.33},\ r^2 = 0.83, \qquad (1)$$

where W=mean weight-at-age transformed from pounds to kilocalories (592 Kcal = 1 lb). Age-specific M for weakfish was estimated by substituting mean weight at age data (ages 0-8) into equation (1).

Based on this analysis, the overall average natural mortality rate (M) for weakfish among all age groups (M = 0.29, SE = 0.06) closely approximated the assumed constant M of 0.3 used by Vaughan et al. 1991 (Table 6). However, the age-specific natural mortality rates (M) from ages 0-8 were inversely related to age and body size, being highest among juvenile weakfish (M = 0.71) and lowest for age 8 weakfish (M = 0.16).

Virtual population analysis was applied to the catch at age matrix presented by Vaughan et al.(1991) for fishing years 1982-1987 using the varying estimates of M; estimates of fishing mortality (mean of ages 2-6), recruitment to age 1, and spawning stock size (in numbers) are compared with those obtained by assuming constant M (0.6 for age 0 and 0.3 for ages 1 and older).

Relatively small differences are noted between these two sets of estimates (Figure 1). However, greater differences are noted in yield per recruit and especially in maximum spawning potential.

estimates of weakfish bycatch to shrimp ratio are presented in Table 11 of Vaughan et al. 1991, and range from 0.02 to 0.66. Shrimping in North Carolina is predominantly in internal waters, with ratio estimates ranging from 0.06 for Core Sound to 0.47 for Pamlico Sound (Wolff 1972). Shrimping in South Carolina and Georgia are predominantly in oceanic waters close to shore during the summer and fall. Recent estimates for South Carolina range from (0.11 to 0.66) (Wenner 1987). Limited estimates are available for Georgia (0.03 to 0.11) (Knowlton 1972). The Georgia estimates have been reduced by 77.4% to reflect a presumed misidentification of _Cynoscion_ _nothus_ for _C. regalis_. No estimates are available for the east coast of Florida where _C. nothus_ predominates.

The subcommittee recommends the use of a weakfish bycatch to shrimp ratio of 0.25:1 as representative for the Southeast Atlantic coastal shrimp fishery. Further, the difference in estimates of F for ages 0 and 1 with and without the bycatch multiplier should be used to augment M (natural mortality), and maximum spawning potential be re-estimated using the F's without bycatch and M's including bycatch. A release mortality of 60% was assumed. Parallel runs based on constant M (0.2, 0.3, 0.4) and varying M (based on M's using the method of Boudreau and Dickie 1989) are given in Figures 4 and 5 representing maximum spawning potential. Note that at low multiples of F (<0.6), MSP decreases with increasing age at entry, reflecting that with high release mortality, increasing age at entry is counterproductive (Figure 5). For larger multiples of F (>0.6), relatively small gains in MSP are available by increasing age at entry.

6. Biological Reference Point

Discussion of biological reference points centered on F_{20} (fishing mortality that results in an equilibrium maximum spawning potential of 20%). The subcommittee recommends that F_{20} be the biological reference point and that this be based on the following scenario:

1. F based on stock assessment mean estimates of F (1982-1986); mean F for age 0 was 0.02 yr^{-1}, mean F for age 1 was 0.54 yr^{-1}, and mean F for ages 2+ was 0.70 yr^{-1}.
2. Difference in F to be included in M based on bycatch ratio of 0.25:1 (0.41 yr^{-1} for age 0 and 0.16 yr^{-1} for age 1).
3. Background M based on constant or underlying values plus augmented by weakfish bycatch as described in (2).
4. Release mortality of 0.60 for analyzing gains through size limits (age at entry).

F multiples and F at ages 0, 1, and 2+ are estimated from items 1-3 given above. For management, these estimated F's need to be viewed in relation to best available estimates for the current level of adult F (2+) of 0.9 to 1.0.

7. Gear Selectivity

Since discard mortality for weakfish is expected to be very high, it is imperative that fish below the minimum legal size limit escape by passing through the meshes during the fishing operation. This requires that minimum mesh size restrictions be imposed by gear type. Management recommendation No. 2 of Amendment 1 specifies that the minimum size limit for the species will increase from 10 inches TL in 1992 to 12 inches TL in 1994.

The ability of a weakfish to escape through or be held by a mesh depends on it's dimensions in relation to the opening of the mesh. For gill nets, theoretical probabilities of capture for weakfish were calculated for a range of mesh sizes using the model of Ehrhardt and Die (1988) and Sechin (1969). The probability of capture is related to the difference between opercular girth and maximum girth and their respective variances.

Morphometric data for weakfish from Scoles (1991) and the Delaware Division of Fish and Wildlife were used to develop the following relationships between total length (TL) and opercular girth (OG) and maximum body girth (MG):

$$OG = 0.497 + 0.416 * (TL)$$

$$MG = 0.439 + 0.464 * (TL).$$

Mesh perimeters (conditioned mesh circumference) were obtained from Meyer and Merriner (1976), based on regressions from those meshes reported in their paper ($R^2 > 0.99$). The model was run for nominal meshes ranging from 2"-6" (Figure 6, Table 7). For a given mesh size, the probability of capture by length class was normalized such that the length class with the maximum probability of capture was set equal to 1.0 . The length classes corresponding to L_{25} and L_{50} were derived from the normalized data sets (Table 8). Empirical data for gill nets fished in Delaware Bay (1979), Virginia (1990), and North Carolina (1989) are compared to the theoretical probabilities for various mesh sizes in Figure 7.

Limited data exist concerning the size selectivity of weakfish for other commercial gears. Meyer and Merriner (1976) presented theoretical and empirical retention lengths for weakfish in Virginia pound nets for mesh sizes ranging from 2-3 inches. Theoretical retention lengths (L_{50}) were similar to values derived in the present analysis (Table 8).

For otter trawls, the relationship between size at entry and mesh size was estimated by determining minimum selection length for openings of various mesh sizes. The length of the diagonal of the mesh opening was calculated from the expression

$$M_o = 2*(1/2M_s)^2 = 0.707\ M_s$$

where:

M_o = mesh opening(mm), and M_s = stretch mesh measurement(mm), and minimum retention length was determined from the relationship between total length and maximum body depth presented by Scoles (1991) (Table 8). Calculated retention lengths represent minimum theoretical values rather than mean selection lengths.

8. Genmod Analysis

GENMOD, an age-structured population model developed by J. Hightower was used to simulate the weakfish population under various management alternatives. The model has been used to determine optimal harvesting strategies for several fish stocks including anchovy, Atlantic menhaden, Pacific ocean perch, bluefish, winter flounder, and summer flounder. A description of the model and its use can be found in Hightower and Grossman (1985, 1987).

The model uses standard fisheries equations to simulate the dynamics of an exploited fish stock. The model requires input data on weight-at-age, fecundity, mortality, and recruitment. These data were derived from Vaughan et al. 1991.

The model is most affected by changes in the S-R relationship, specifically the value of alpha, the slope at the origin of the S-R curve. Alpha can also be defined as the rate at which the population could grow if there was no inhibition due to parent stock size.

Alpha was estimated using alternative techniques based on life history parameters (Table 9). Specifically, these methods estimate alpha or r_m, the innate or intrinsic ability of a population to increase in size under favorable environmental conditions. Values of r_m are then converted to alpha. Based on the four methods, alpha ranged from 1.25 to 3.09. Because the r_m derived from Hoenig's equation (3.09) was significantly different from the others, this value was not used to derive a mean alpha. Based on the other values, a mean alpha of 1.325 was derived.

The beta term of the S-R relationship was estimated by incremental adjustment of the the S-R relationship to derive an MSY value of approximately 30 million pounds. Commercial and recreational landings since 1979 have averaged approximately 31 million pounds.

Because the model begins with age-1 recruits, fishing mortality on age-0 weakfish was simulated by adjusting the alpha value to account for this mortality rate (M. Gibson pers. comm.). Based on VPA results (Vaughan et al. 1991) the alpha value was reduced by 26% to account for this age 0 mortality.

The model was first run to determine the spawning stock biomass (SSB) associated with specific fishing mortality rates. This allowed the determination of the SSB equal to 5%, 10%, 15%, 20%, 25%, and 30% of the unfished level. The 20% value has been used for some groundfish (e.g., cod, yellowtail, winter flounder) and other fish species (red drum, scup) to define the minimum level at which the stock can sustain itself over an extended period of time. The 10% level can be used to define the level below which the probability of recruitment failure is high. The other values were presented for illustrative purposes.

Using the 5% to 30% values as targets, the model was then run to determine the probability of reaching these values in 5 and 10 years under the various management alternatives. In order to simulate random variability in recruitment (i.e., due to environmental effects), a multiplicative lognormal error term was used. Hightower and Grossman (1985) suggested that this term ranged from 0.25 to 0.75 for most fish stocks.

The error term can be estimated from a series of recruitment data by calculating the mean and standard deviation from a log transformed index and then dividing the standard deviation by the mean to calculate the mean square error (MSE). Because the MSE represents the variability in recruitment due to both environmental factors and spawning stock size, it is an overestimate of the lognormal error term. Using the YOY index obtained from several sources (Vaughan et al. 1991) the calculated average MSE would be 0.49. Assuming 75% of the MSE is due to environmental effects, an estimate of the lognormal error term would be 0.37.

An equilibrium age vector (numbers-at-age) and an average fishing mortality rate of 1.0 for age 3+ fish for 10 years was used to derive a starting age vector for the weakfish population as input into the model. This rate approximates the average fishing mortality experienced by age 3 fish in the stock in the most recent years. Based on VPA results, age 1 and age 2 fish experienced 71% and 76% of the adult F during this period (Vaughan et al. 1991).

Model results indicated that the probability of reaching a 20% MSP value in 5 years decreased as the mean F increased (Figure 8). For example, there was about a 10% chance that an average F of 0.7 would result in a % MSP at the end of 5 years of 20% or greater whereas an F of 0.3 resulted in a probability of approximately 80%. In addition, as the time scale increased to 10 years, the probability of reaching the target % MSP increased (Figure 9). The probability that an average F of 0.7 would allow the stock to rebuild to a 20% MSP level or greater was about 45% and an F of 0.3 had an associated probability of nearly 100%. Based on the strategy adopted by the ASMFC Weakfish Management Board the probability of reaching a 20% MSP in 5 years and 10 years is about 35% and 95%, respectively.

It is important to note that the associated probabilities reflect the assumptions associated with the input data. For example, if the mortality on age-1 fish is reduced due to the implementation of mesh regulations or minimum fish size, the associated probabilities would increase. Alternatively, if the variable associated with the effects of environmental factors on recruitment was less than 0.37, the value that we assumed for the model, the associated probabilities would decline. In addition, if the current (1991) population is more reduced than suggested by the initial population estimates generated by the simulation, then the associated probabilities are overestimates, that is, a more reduced spawning stock would make it more difficult to build to the desired level of spawning stock biomass in the specified period of time.

9. Recreational Bag/Size Limits

MRFSS intercept data from the years 1989 to 1990 were used to determine the impact of alternative possession/size limits on weakfish recreational landings. Specifically, catch frequencies derived from MRFSS data sets (Type A fish) were used with an algorithm originally derived to determine the effects of potential possession limits on recreational catches of spanish and king mackerel in the Gulf and South Atlantic. All calculations assumed a post-release mortality of 25%. Catch frequencies from 1989 and 1990 were used because the ASMFC Weakfish S&S Committee determined that these years were representative of future recreational landings of weakfish.

MRFSS data indicated that over 7% and 2% of the successful angler trips in these years would have been affected by a 5 and 10 fish possession limit, respectively (Table 10). Based on a comparison of the number of trips landing any size weakfish and only those trips where only 12" TL or larger fish were landed, approximately 85% of the trips would have been impacted in those same years by the 12" minimum size. Similarly, 72% of angler trips would have been effected by a 13" TL minimum size.

The reduction strategy approved by ASMFC calls for a reduction in exploitation of at least 15% in year 1 followed by an additional reduction of 10% in year 2 (for a total of 25%). The percent reduction in exploitation associated with a 7 fish possession limit and a 11" TL minimum size would have been approximately 15% for the years 1989 and 1990 combined (Table 10). A 10 fish possession limit in combination with a minimum size of 13" TL would approximate the second year target of 25%. In addition, a limit of 5 fish and a 12" TL minimum size would have had an associated reduction of about 26%.

10. Exploitation Reductions - Size Limit/Bycatch Interactions

The Weakfish Management Board requested that the SSC evaluate the potential reductions in annual exploitation that would result from the imposition of a minimum size limit. This request was extended further to include the estimation of reductions in exploitation which would occur in the weakfish fishery if minimum size limits were imposed in combination with reductions in bycatch in the south Atlantic shrimp trawl fishery.

To answer these questions, the YPR and SSB/R analyses (see Vaughan et al. 1991) were rerun incorporating simultaneous reductions in F due to shrimp fishery bycatch reductions and the imposition of minimum size limits ranging from 8-18 inches TL. The analysis was run assuming 100, 50, and 0 % of current bycatch and a 60% post-release mortality rate of the proportion of sublegal fish retained by commercial gears (i.e., the analysis assumed the implementation of mesh size corresponding to L_{25} for a given minimum size limit).

Resultant reductions in F were converted to reductions in annual exploitation. Results are expressed as the additional reductions necessary to achieve a total reduction in annual exploitation of 25% for minimum size limits ranging from 8-16 inches for the three levels of bycatch described above (Table 11).

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Table 1. Catch curve analysis estimates of Z (and F for M = 0.3) for Atlantic coast weakfish based on recreational fishery catch and length frequency data, 1982-1990. Semi-annual age length keys applied to 1982-1988, and mean applied to 1989-1990.

Year	Z	SE(Z)	R^2	F	3-Y[b]
		Catch Curve Based on Ages 1-6			
1982[a]	0.43	0.05	0.93	0.13	-
1983	0.63	0.21	0.62	0.33	0.30
1984	0.74	0.14	0.84	0.44	0.43
1985	0.83	0.17	0.82	0.53	0.60
1986[a]	1.12	0.13	0.94	0.82	0.71
1987	1.08	0.12	0.94	0.78	0.64
1988	0.62	0.27	0.45	0.32	0.62
1989	1.06	0.17	0.89	0.76	0.72
1990	1.38	0.11	0.97	1.08	-
		Catch Curve Based on Ages 2-6			
1982	0.43	0.08	0.87	0.13	-
1983[a]	0.95	0.16	0.90	0.65	0.48
1984[a]	0.96	0.11	0.95	0.66	0.71
1985[a]	1.11	0.05	0.99	0.81	0.72
1986	0.98	0.15	0.91	0.68	0.81
1987[a]	1.23	0.13	0.96	0.93	0.77
1988[a]	1.01	0.23	0.82	0.71	0.88
1989[a]	1.30	0.14	0.97	1.00	0.99
1990[a]	1.55	0.08	0.99	1.25	-

[a] Best estimate (full recruitment generally with age 2).

[b] Three year running average (y-1, y, y+2).

Table 2. Length-based estimates of total mortality (Z) for Atlantic coast weakfish based on length frequencies from the recreational fishery, 1979-1989. The length at full recruitment (L_1) expressed as the arithmetic mean (L). The average length was was estimated from the data. The mean Z in year t was expressed as the Z in years t+2, t+1, and t.

Year	L_1 (inches, TL)	L	Z	Mean Z t+2, t
1979	17.0	21.04	0.55	0.46
1980	19.0	24.49	0.34	0.44
1981	24.0	26.70	0.50	0.50
1982	29.0	30.56	0.47	0.50
1983	14.0	18.94	0.53	0.52
1984	17.0	21.51	0.49	0.68
1985	13.0	17.99	0.55	0.83
1986	13.0	15.38	1.01	1.00
1987	13.0	15.71	0.92	0.92
1988	16.0	17.87	1.08	-
1989	13.0	16.48	0.77	-

Table 3. Length-based estimates of total mortality (Z) for Atlantic coast weakfish based on length frequencies from the recreational fishery, 1979-1989. The length at at full recruitment (L_1) to the recreatonal fishery was estimated from the data. The average length was expressed as the median length (L_{med}). The mean Z in year t was expressed as the Z in years t+2, t+1, and t.

Year	L_1 (inches,TL)	L_{med}	Z_{med}	Mean Z t+2, t
1979	17.0	19.0	1.00	0.72
1980	19.0	23.0	0.49	0.72
1981	24.0	26.0	0.67	0.74
1982	29.0	30.0	0.73	0.85
1983	14.0	17.0	0.82	0.89
1984	17.0	19.0	1.00	1.19
1985	13.0	16.0	0.86	1.42
1986	13.0	14.0	1.70	1.66
1987	13.0	17.0	1.70	1.47
1988	16.0	15.0	1.58	1.31
1989	13.0	15.0	1.14	-
1990	11.0	13.0	1.20	-

Table 4. Length-based estimates of total mortality (Z) for Atlantic coast weakfish based on length frequencies from the NEFC commercial trawl fishery, 1983-89. The Z_l value refers to total mortality based on the arthmetic mean length (L), and Z_{med} refers to the total mortality based on the median length (L_{med})

Year	Z_l	Z_{med}
1983	0.68	1.18
1984	0.78	1.18
1985	1.04	1.74
1986	1.28	1.66
1987	0.75	1.18
1988	0.95	1.11
1989	0.78	0.88
Mean	0.89	1.28
SE	0.08	0.12

Table 5. Length-based estimates of total mortality (Z) for Atlantic coast weakfish based on length frequencies from the North Carolina winter trawl fishery, 1982-89. The Z_l value refers to the total mortality estimate based on the arithmetic mean length (L), and the L_{med} value refers to the total mortality calculated from the median length (L_{med}).

Year	Z_l	L_{med}
1982	1.01	1.81
1983	1.01	1.81
1984	1.35	1.81
1985	1.73	1.81
1986	1.29	1.81
1987	1.43	1.81
1988	1.80	1.81
1989	1.02	1.81
Mean	1.33	1.81
SE	0.11	-

Table 6. Estimates of age-specific natural mortality (M) and their 95% confidence intervals (CI) for weakfish based on the average weight-age and the exponential regression model of Boudreau and Dickie (1989).

Age	Mean Weight (lbs)	95% CI weight	Mean[1] M	95% CI M
0	0.12	0.10 - 0.14	0.71	0.67 - 0.75
1	0.56	0.49 - 0.63	0.42	0.41 - 0.44
2	1.21	1.14 - 1.28	0.33	0.32 - 0.34
3	1.65	1.55 - 1.75	0.30	0.30 - 0.30
4	3.67	3.23 - 4.11	0.23	0.22 - 0.24
5	7.15	6.70 - 7.60	0.18	0.18 - 0.19
6	8.28	7.86 - 8.70	0.17	0.17 - 0.18
7	9.85	9.21 -10.49	0.16	0.16 - 0.17
8	11.04	10.39 -11.69	0.16	0.16 - 0.16

[1] $M = 2.88 * w^{-0.33}$

where: w is the average weight in Kcal (592 Kcal = 1 lb).

Table 7. Theoretical probability of capture of weakfish in gill nets of a specified nominal mesh by length class (TL cm).

TOTAL LENGTH CLASS	MESH SIZE 2"	MESH SIZE 2.125"	MESH SIZE 2.25"	MESH SIZE 2.375"	MESH SIZE 2.5"	MESH SIZE 2.675"	MESH SIZE 2.75	MESH SIZE 2.875"
10								
11								
12								
13	0.002							
14	0.0011	0.0003						
15	0.0043	0.0015	0.0002					
16	0.0137	0.0055	0.0009					
17	0.0369	0.0171	0.0038	0.0003				
18	0.0826	0.0445	0.0124	0.0015	0.0004			
19	0.1551	0.0965	0.0343	0.0057	0.0018			
20	0.2445	0.1757	0.0791	0.0179	0.0065	0.0003		
21	0.3246	0.2688	0.1528	0.0469	0.0201	0.0016		
22	0.3644	0.347	0.2484	0.1026	0.0518	0.0059	0.0007	
23	0.347	0.3792	0.3407	0.1887	0.1116	0.0185	0.0031	0.0001
24	0.2815	0.3523	0.3957	0.2926	0.2024	0.0485	0.0107	0.0016
25	0.1952	0.2793	0.3909	0.3839	0.3097	0.1071	0.031	0.0059
26	0.116	0.1896	0.3297	0.428	0.4016	0.1989	0.0748	0.0188
27	0.0593	0.1105	0.2383	0.4073	0.4432	0.3123	0.1519	0.0496
28	0.0261	0.0555	0.1481	0.3321	0.4181	0.4162	0.2606	0.1102
29	0.0099	0.024	0.0793	0.2329	0.3385	0.4731	0.3792	0.2066
30	0.0033	0.009	0.0367	0.1409	0.2362	0.4609	0.4704	0.3282
31	0.0002	0.0029	0.0147	0.0737	0.1423	0.3864	0.4998	0.4439
32			0.0051	0.0333	0.0743	0.2799	0.4571	0.5141
33			0.0011	0.0131	0.0336	0.1757	0.3614	0.5124
34				0.0044	0.0131	0.0957	0.2479	0.4416
35					0.0044	0.0453	0.1477	0.3304
36						0.0186	0.0766	0.2152
37						0.0066	0.0345	0.1221
38							0.0135	0.0603
39							0.0045	0.0259
40								0.0097
41								0.0012
42								
43								
44								
45								

TOTAL LENGTH CLASS	MESH SIZE 3"	MESH SIZE 3.125	MESH SIZE 3.25"	MESH SIZE 3.5"	MESH SIZE 3.75"	MESH SIZE 4"	MESH SIZE 4.5"	MESH SIZE 5"	MESH SIZE 5.5"	MESH SIZE 6"
25	0.0007									
26	0.0032									
27	0.011	0.0016								
28	0.0317	0.006	0.0005							
29	0.077	0.0189	0.0031							
30	0.1572	0.0502	0.0109							
31	0.2719	0.1123	0.0316							
32	0.3999	0.2122	0.0772	0.0032						
33	0.5032	0.3407	0.159	0.011						
34	0.5446	0.4671	0.2779	0.032						
35	0.5098	0.5505	0.4142	0.0784	0.003					
36	0.4145	0.5608	0.5298	0.1621	0.0108					
37	0.2937	0.4965	0.5854	0.2848	0.0317					
38	0.1817	0.3835	0.5622	0.4279	0.0779	0.0026				
39	0.0981	0.259	0.4713	0.5538	0.1621	0.0106				
40	0.0462	0.153	0.3461	0.6218	0.287	0.0312				
41	0.0189	0.079	0.2228	0.6097	0.4357	0.0772				
42	0.0066	0.0356	0.1257	0.5248	0.5715	0.1614				
43		0.014	0.062	0.3976	0.6531	0.2878				
44		0.0028	0.0267	0.2654	0.655	0.4408				
45			0.0099	0.1558	0.5798	0.5851	0.0104			
46				0.0803	0.4543	0.6794	0.031			
47				0.0362	0.3151	0.6957	0.0768			
48				0.0141	0.193	0.6323	0.1615			
49					0.1041	0.5115	0.2901			
50					0.0492	0.3682	0.449			
51					0.0202	0.2352	0.6056	0.0066		
52						0.1326	0.7198	0.0299		
53						0.0658	0.762	0.0748		
54						0.0284	0.7241	0.1584		
55							0.6197	0.2868		
56							0.4772	0.4485		
57							0.3291	0.6134		
58							0.2019	0.7435	0.0288	
59							0.1095	0.8095	0.0741	
60							0.0521	0.7999	0.1573	
61								0.7206	0.2858	
62								0.5912	0.449	
63								0.439	0.6183	
64								0.2926	0.7582	0.0047
65								0.1735	0.8411	0.0732
66								0.0908	0.8552	0.1562
67								0.0234	0.8023	0.2844
68									0.6941	0.4481
69									0.5498	0.6198
70									0.3947	0.7567
71									0.2541	0.8604
72									0.1453	0.8934
73									0.0561	0.8656
74										0.7831
75										0.6568
76										0.5047
77										0.351
78										0.2183
79										0.1042

Table 8. Weakfish retention lengths (L_{25} = 25%, L_{50} = 50%) for various mesh sizes by gear.

MESH SIZE (IN)	GILL NET[1] L_{25}	GILL NET[1] L_{50}	OTTER TRAWL[2] L_{25}	OTTER TRAWL[2] L_{50}	POUND NET[3] EXP	POUND NET[3] THEO
2.000	7.1	7.6	6.2	7.2	8.0	7.5
2.125	7.5	7.9	6.9	7.7	-	-
2.250	8.0	8.5	7.1	8.1	8.6	8.0
2.500	9.0	10.0	8.0	9.0	10.4	8.6
2.750	10.4	11.0	9.0	10.0	10.6	9.3
3.000	11.7	12.2	10.0	11.0	10.5	10.2
3.125	12.4	12.8	10.7	11.7	-	-
3.250	13.0	13.4	10.9	11.9	-	-
3.500	13.7	14.6	11.9	12.9	-	-
3.750	15.4	15.9	12.8	13.8	-	-
4.000	16.6	17.1	13.8	14.8	-	-

[1] Theoretical selection based on morphometric data presented by Scoles (1991).

[2] Theoretical values based on maximum body depth (BD)/total length (TL) relationships: BD = 1.755 + (0.187*TL) (Scoles 1991).

[3] Meyer and Merriner (1976).

Table 9 . Indirect methods for estimating alpha based on life history parameters.

Source	Equation	Input	Alpha
Hoenig et al. (1987)	$r = 425.2 * t_m^{-0.949}$	t_m = 730	3.09
Cushing (1973)	$alpha = 1.98 + 0.0306*F^{0.33}$	F = $86*10^3$	1.56
Longhurst (1983)	r = 3K[(Linf/L)-1]	Linf = 36 inches L = 23.0 K = 0.24	1.37
Boudreau and Dickie (1989)	$r = 2.88 * w^{-0.33}$	w = 527Kcal	1.25

Table 10. The effect of various size and possession limits on coastwide recreational landings (MRFSS Type A fish) of weakfish, 1989-90. The Table contains the percent reduction in the number of weakfish killed by anglers. Reductions were calculated assuming a post-release mortality of 25%.

Possession Limit	Size Limit (TL inches)							
	NONE	10	11	12	13	14	15	16
NO.	-	1.64	4.62	10.38	20.82	31.77	39.84	45.40
1	44.53	45.46	46.98	49.06	53.20	56.47	59.94	62.23
2	31.58	32.77	34.61	37.35	43.23	48.15	52.66	56.17
3	24.02	25.29	27.40	30.60	37.58	43.36	48.54	52.69
4	19.30	20.54	22.92	26.41	34.03	40.45	46.07	50.44
5	15.86	17.19	19.60	23.36	31.47	38.30	44.33	49.06
6	13.68	15.05	17.54	21.45	29.77	37.10	43.34	48.23
7	11.85	13.26	15.88	19.93	28.42	36.12	42.62	47.64
8	10.39	11.85	14.61	18.80	27.40	35.37	42.04	47.18
9	9.14	10.61	13.48	17.83	26.56	34.76	41.61	46.95
10	8.03	9.56	12.48	17.05	25.91	34.29	41.28	46.71
11	7.29	8.84	11.69	16.44	25.43	33.93	41.09	46.57
12	6.56	8.12	11.00	15.84	24.94	33.60	40.90	46.43
13	5.90	7.48	10.39	15.31	24.54	33.34	40.73	46.29
14	5.27	6.87	9.85	14.84	24.19	33.13	40.62	46.18
15	4.74	6.35	9.39	14.40	23.88	32.93	40.51	46.07
16	4.33	5.95	8.98	14.06	23.61	32.80	40.43	45.99
17	4.00	5.62	8.66	13.76	23.39	32.73	40.40	45.96
18	3.68	5.29	8.33	13.49	23.20	32.65	40.37	45.93
19	3.35	4.96	8.00	13.23	23.02	32.57	40.34	45.90
20	3.02	4.66	7.70	12.99	22.83	32.49	40.31	45.87

Table 11. Percent reductions in exploitation necessary to achieve first-year target F[1] for weakfish. Reductions were calculated for minimum sizes from 8" to 18" TL and are based on three bycatch levels in the shrimp fishery and F's based on Murphy VPA from Vaughan et al. (1991).

	% of Current Shrimp Bycatch		
Minimum size	100	50	0
8	25	16	4
9	23	15	2
10	20	12	0
11	18	8	0
12	16	5	0
13	13	0	0
14	10	0	0
15	5	0	0
16	3	0	0
17	0	0	0
18	0	0	0

[1] Calculations were made assuming that a 25% reduction in annual exploitation is necessary to achieve the first year target F.

Figure 1. Comparison of the effect of the assumption of constant vs. variable natural mortality rates (M) on estimates of weakfish (a) recruitment to age 1, (b) spawning stock size and (c) adult fishing mortality rate.

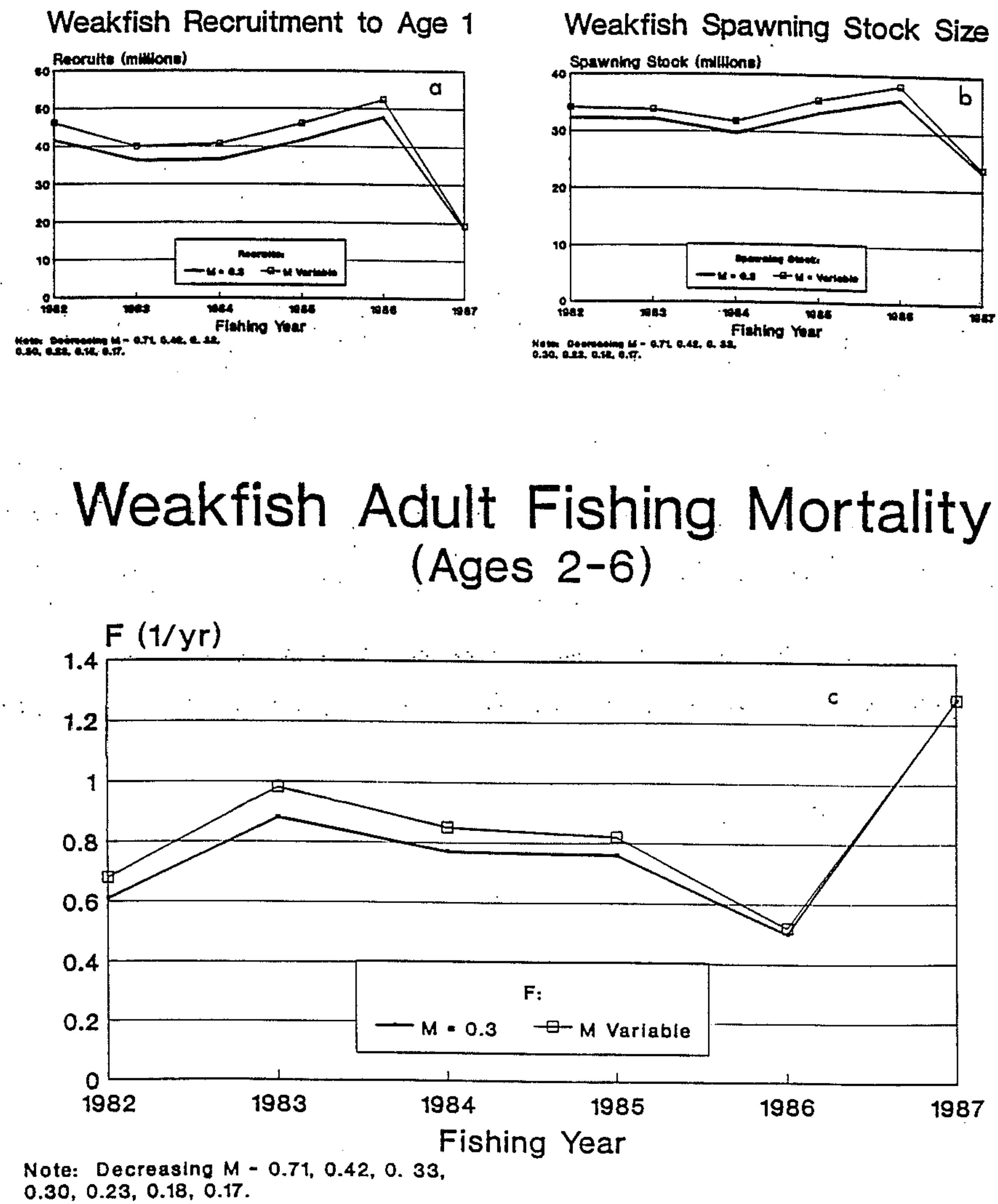
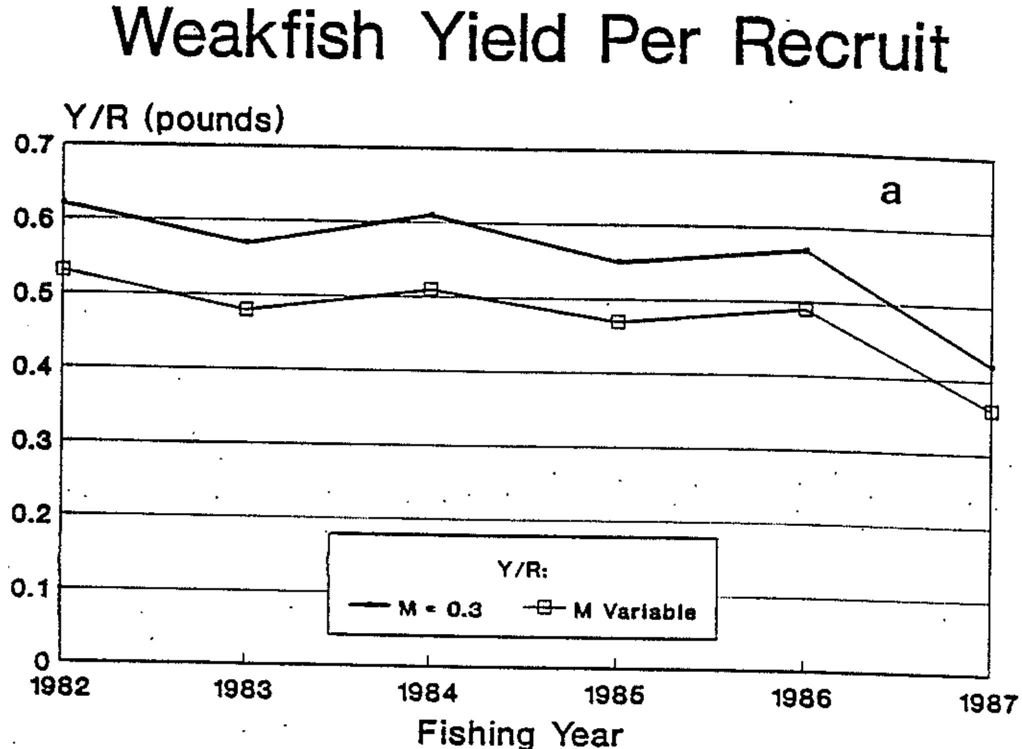
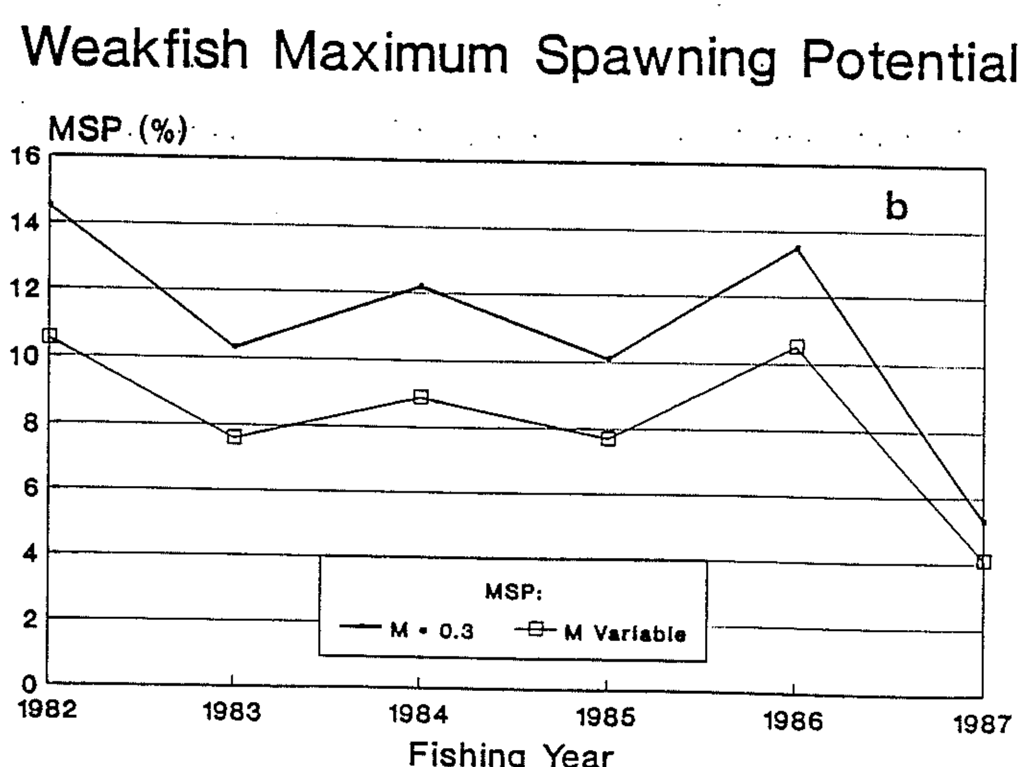


Figure 2. Comparison of the effect of the assumption of constant vs. variable natural mortality rates (M) on estimates of weakfish (a) yield per recruit, and (b) maximum spawning potential.



Note: Decreasing M - 0.71, 0.42, 0.33, 0.30, 0.23, 0.18, 0.17



Note: Decreasing M - 0.71, 0.42. 0.33, 0.30, 0.23, 0.18, 0.17

Figure 3. The effect of release mortality on expected gains in maximum spawning potential from increasing age at entry for weakfish.

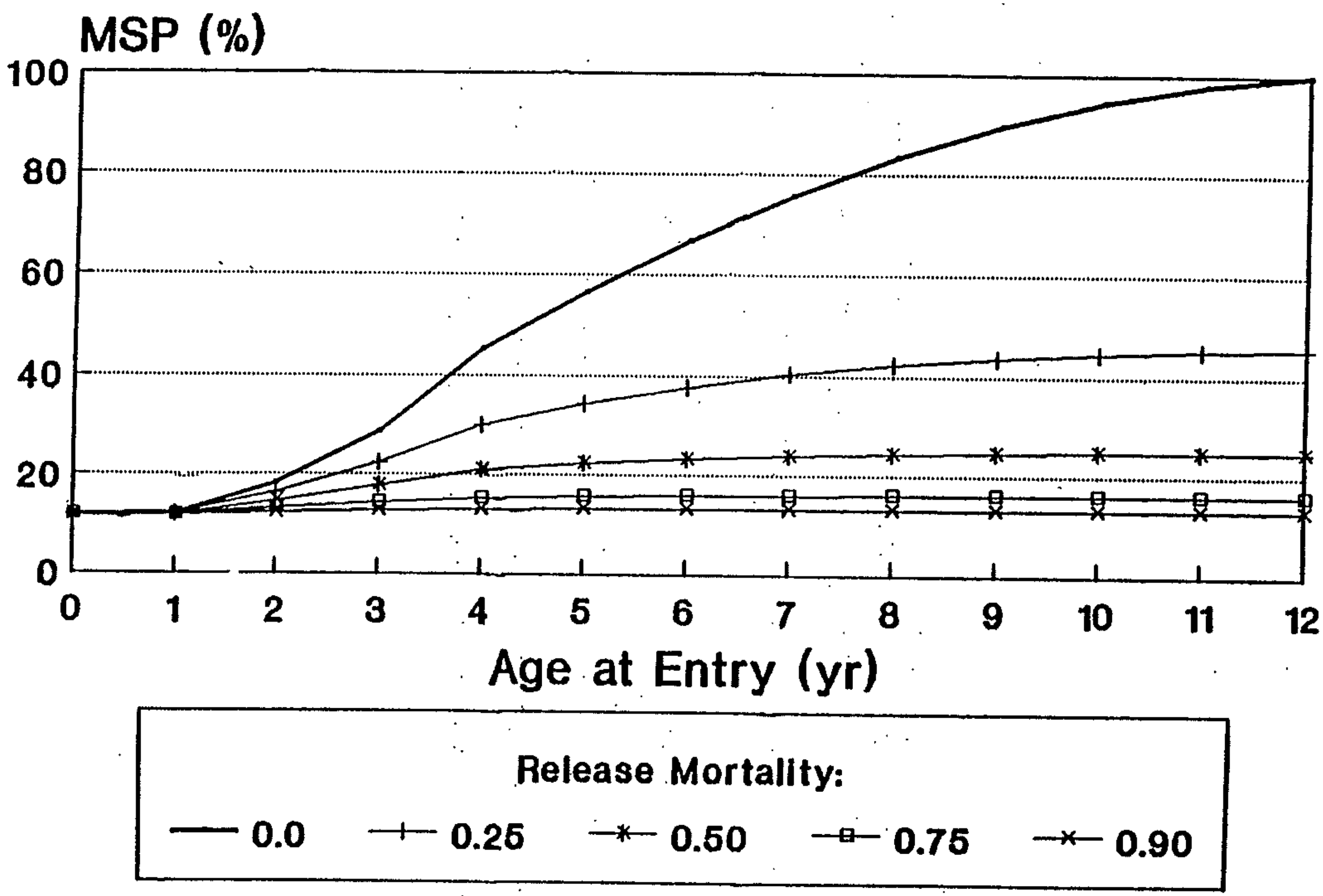


Figure 4. Weakfish maximum spawning potential (a) for fishing years 1982-1987 with bycatch F incorporated in M and (b) by age at entry for constant vs. variable M assuming mean 1982-1986 F, 60% release mortality and bycatch ratio of 0.25.

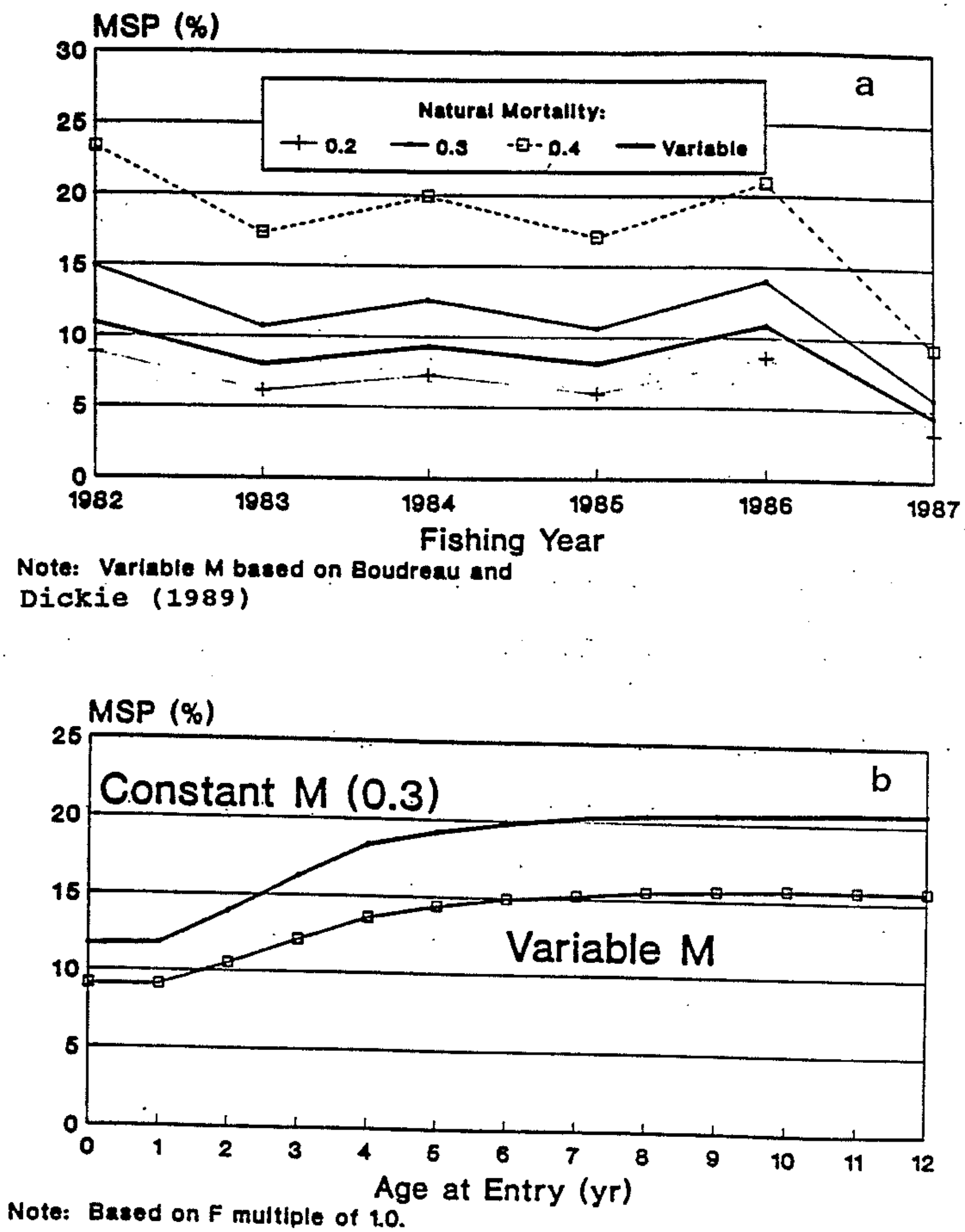


Figure 5. Weakfish maximum spawning potential for ages at entry 1-3 assuming (a) constant M of 0.3 for ages 2-12 and (b) variable M based on Boudreau and Dickie 1989.

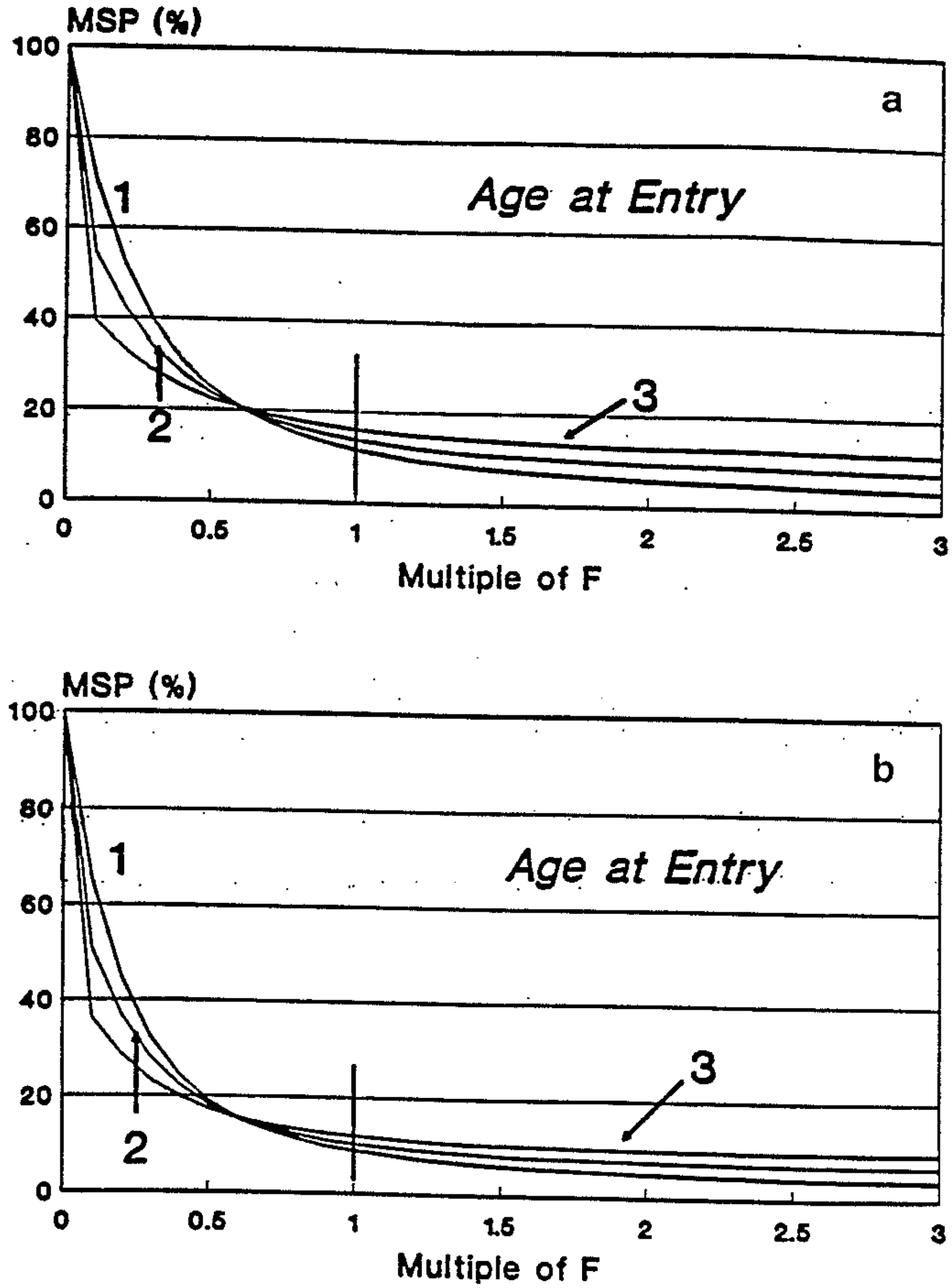
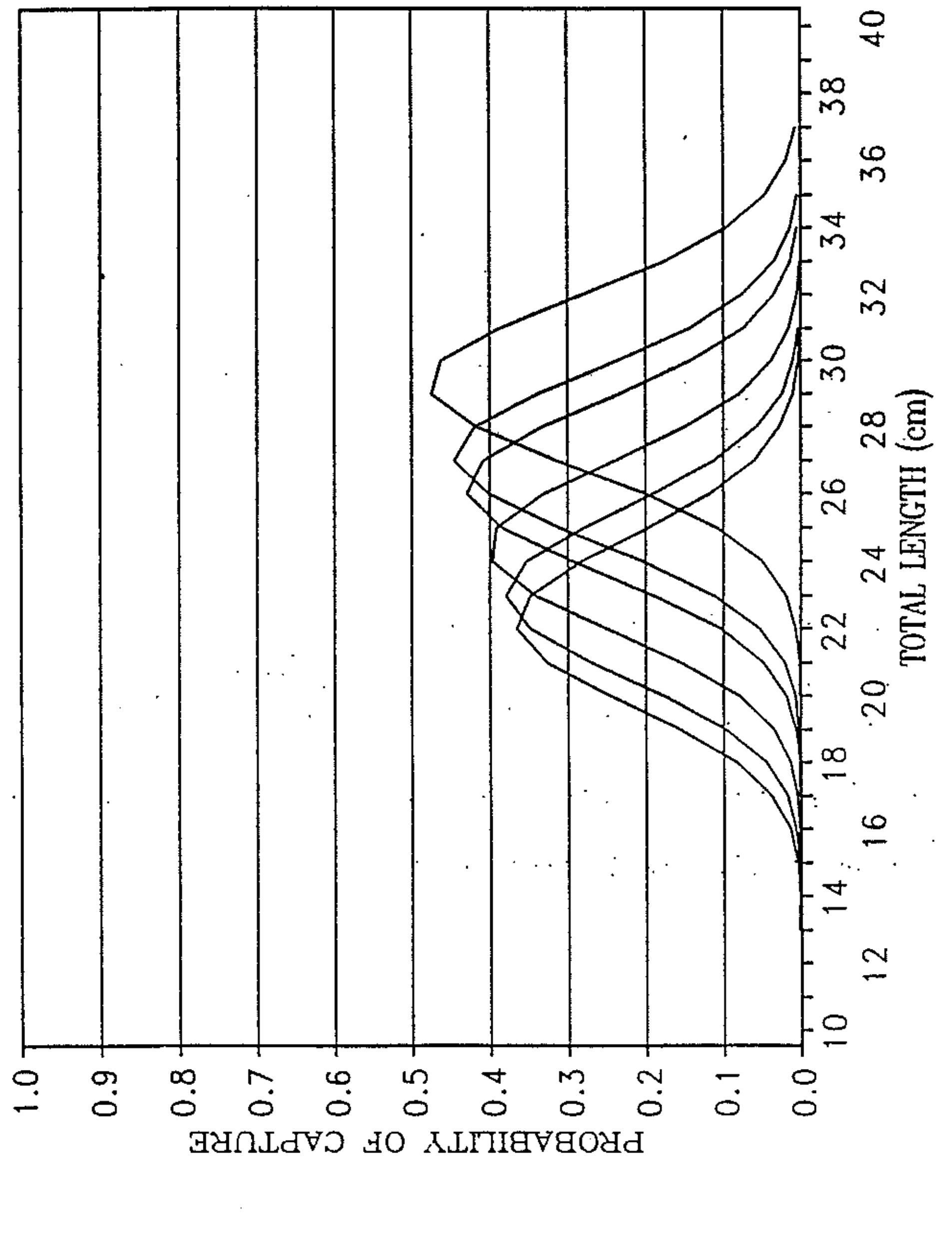
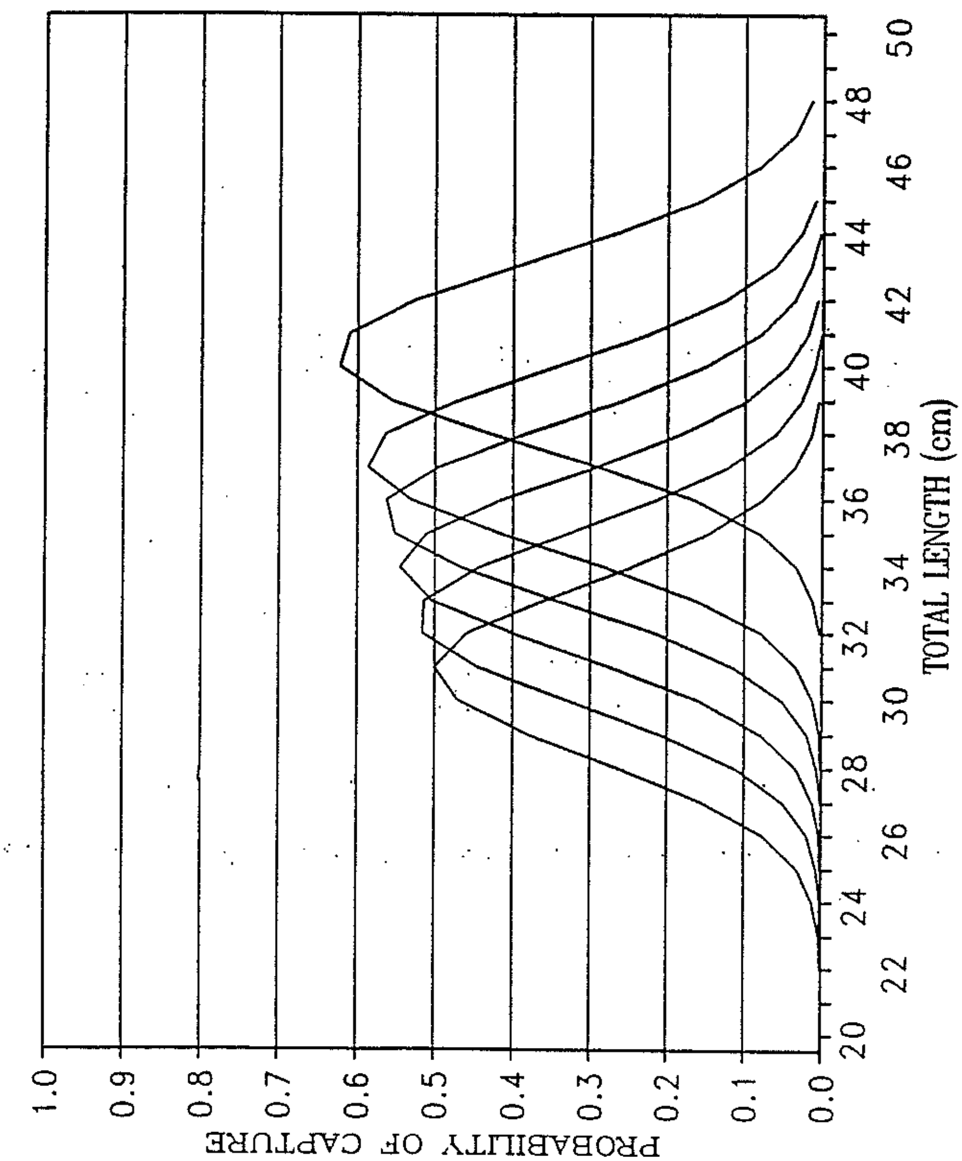


Figure 6. Theoretical probability of capture of weakfish vs. TL (cm) for nominal mesh sizes (inches) from left to right (a) 2, 2.125, 2.25, 2.375, 2.5, 2.625; (b) 2.75, 2.875, 3, 3.125, 3.25, 3.5; (c) 3.75, 4, 4.5, 5, 5.5, 6.

(a)


PROBABILITY OF CAPTURE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
TOTAL LENGTH (cm)
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40

(b)


PROBABILITY OF CAPTURE
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TOTAL LENGTH (cm)
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50

(c)

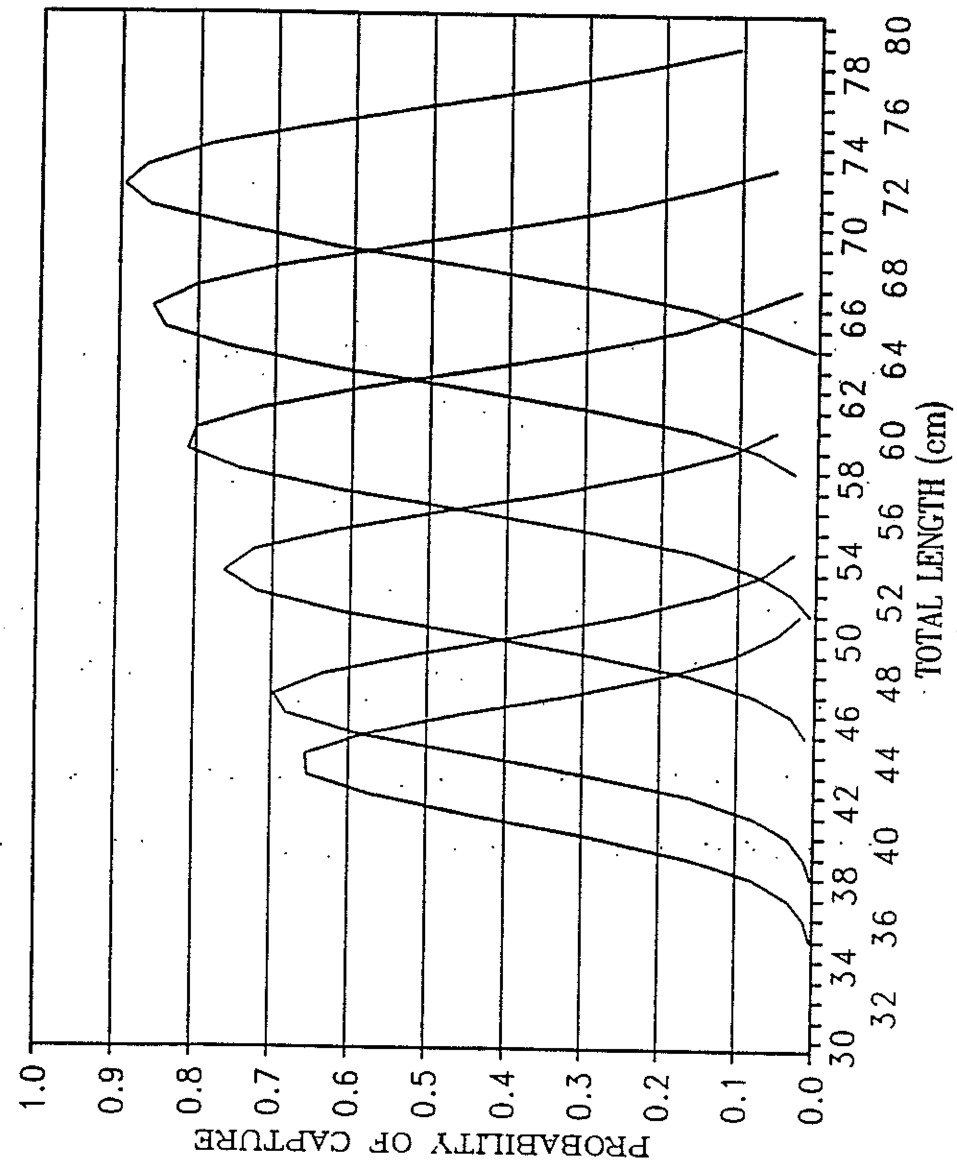
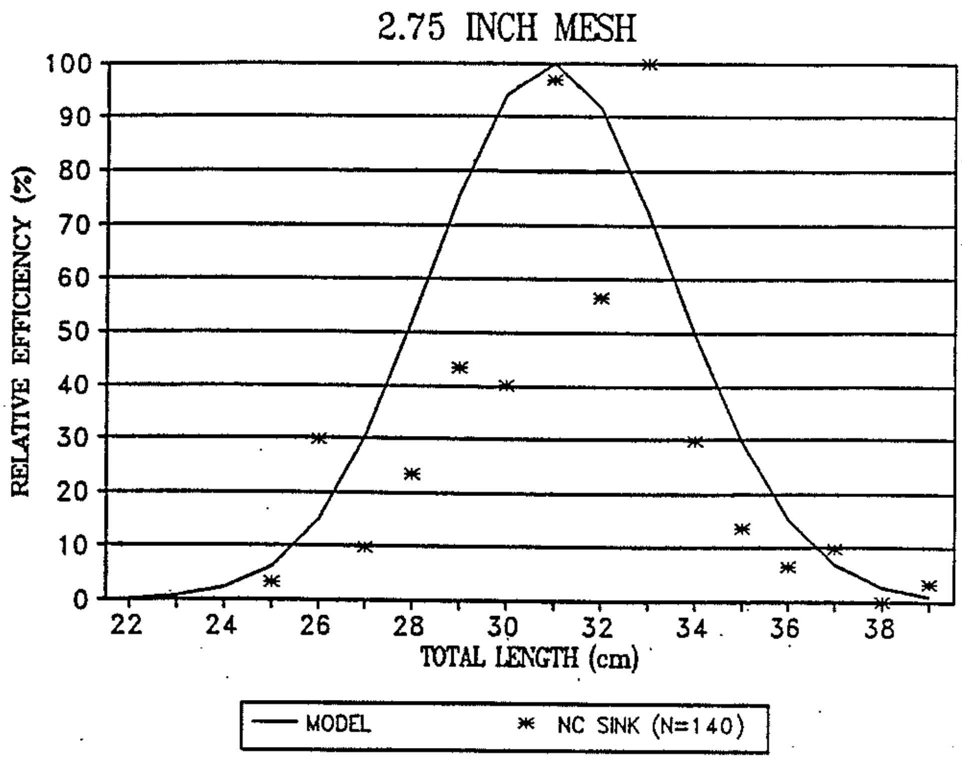

PROBABILITY OF CAPTURE
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
TOTAL LENGTH (cm)
30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80

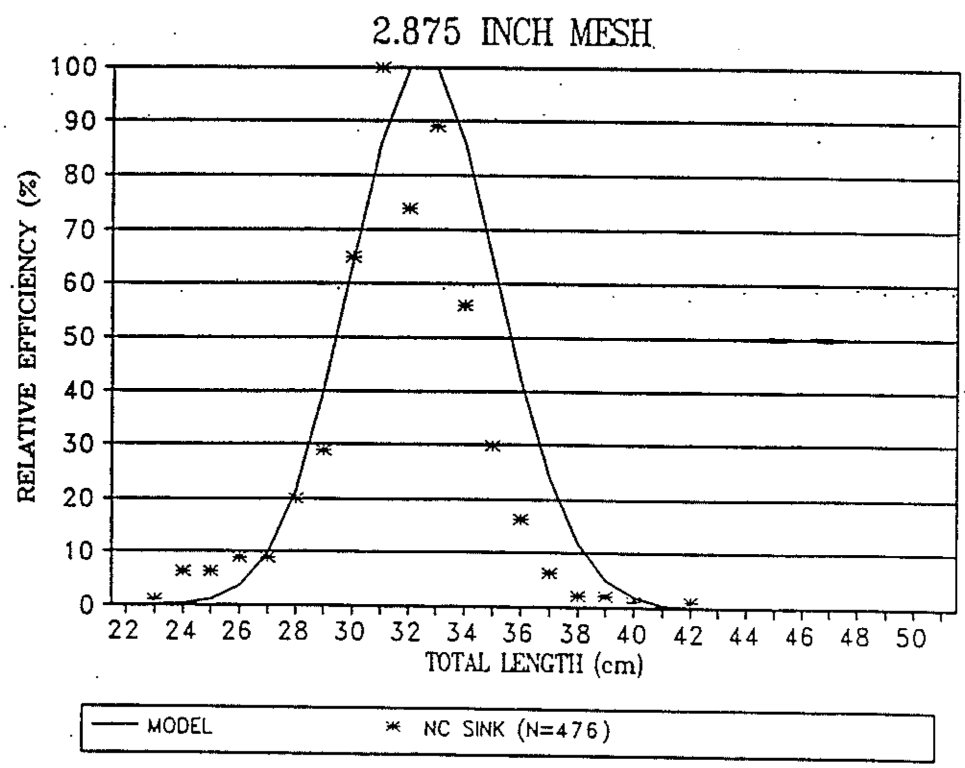
Figure 7. Theoretical relative efficiencies vs. empirical weakfish total length[1] (cm) for meshes of (a) 2.75 in, (b) 2.875 in, (c) 3 in, (d) 3.125 in, (e) 3.25 in, (f) 3.5 in and (g) 3.75 in.

[1] NC sink net data provided by L. Mercer (NC Div. of Marine Fisheries); VA anchor net data provided by R. O'Reilly (VA Marine Resources Commission); De anchor net data provided by R. Seagraves.

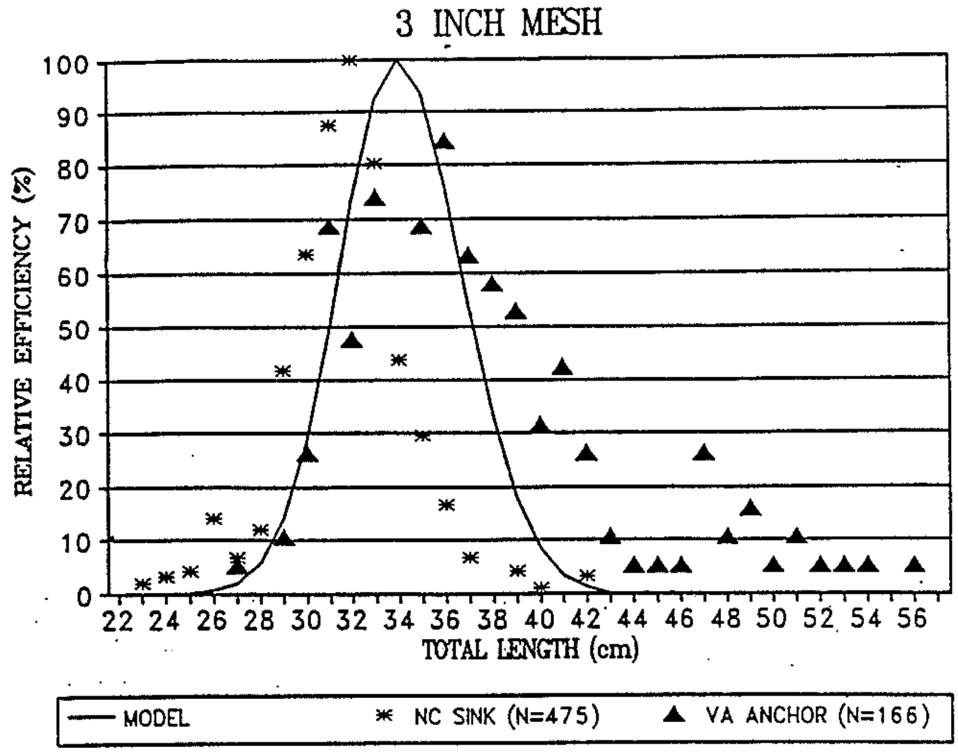
(a)


2.75 INCH MESH
RELATIVE EFFICIENCY (%)
100
90
80
70
60
50
40
30
20
10
0
22 24 26 28 30 32 34 36 38
TOTAL LENGTH (cm)
MODEL
NC SINK (N=140)

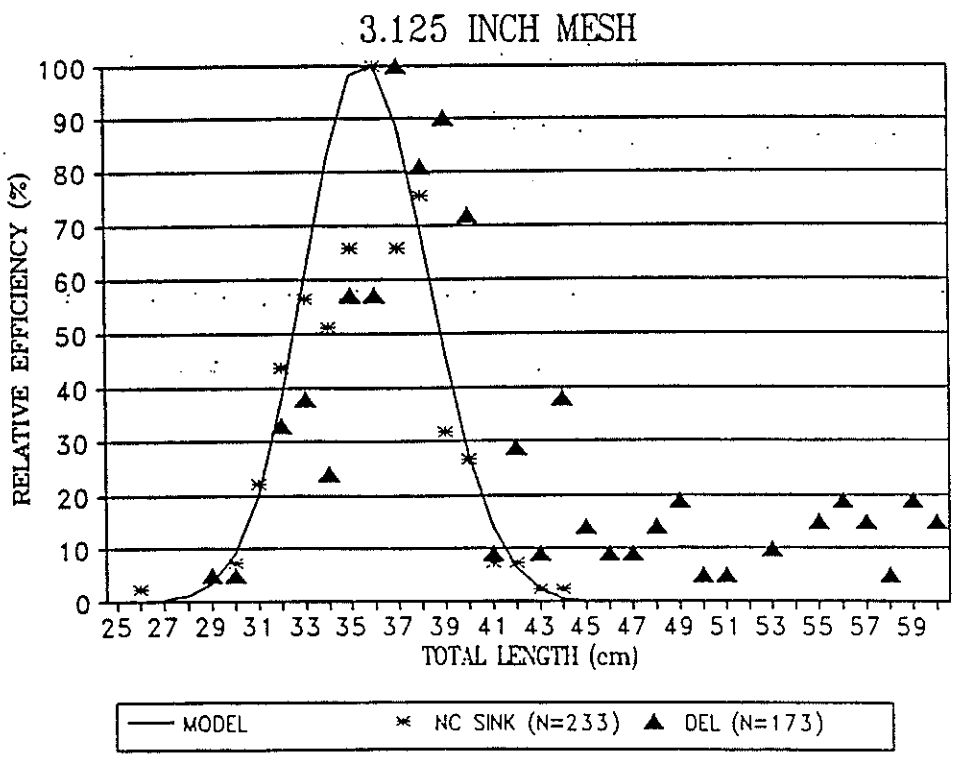
(b)


2.875 INCH MESH
RELATIVE EFFICIENCY (%)
100
90
80
70
60
50
40
30
20
10
0
22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
TOTAL LENGTH (cm)
MODEL
NC SINK (N=476)

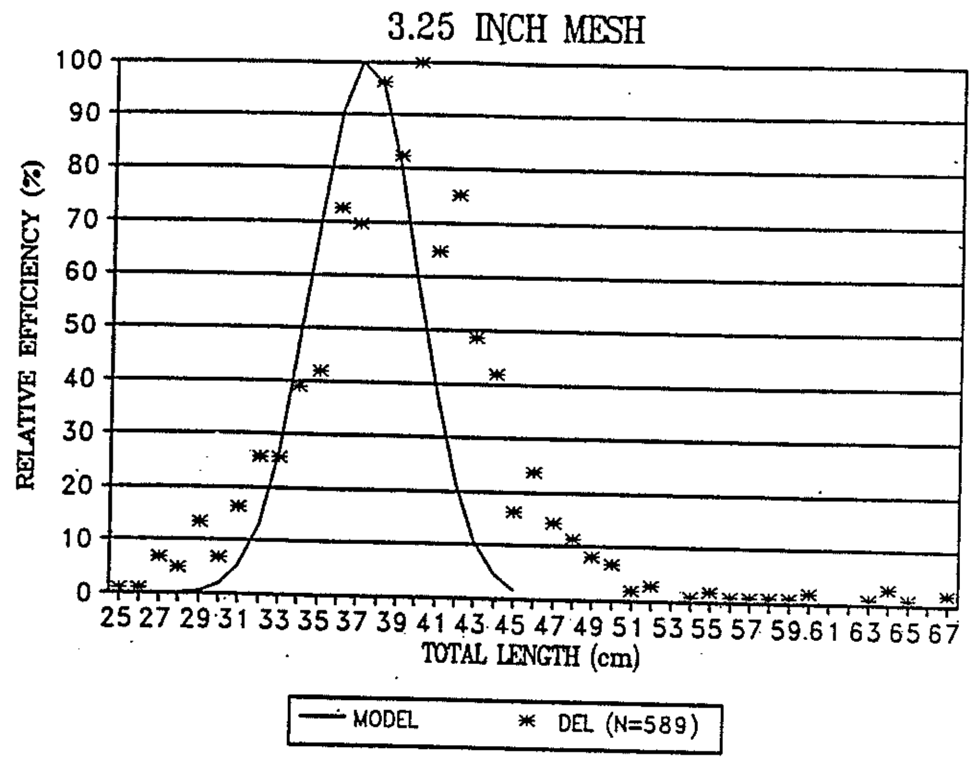
(c)


3 INCH MESH
RELATIVE EFFICIENCY (%)
0
10
20
30
40
50
60
70
80
90
100
22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56
TOTAL LENGTH (cm)
MODEL
NC SINK (N=475)
VA ANCHOR (N=166)

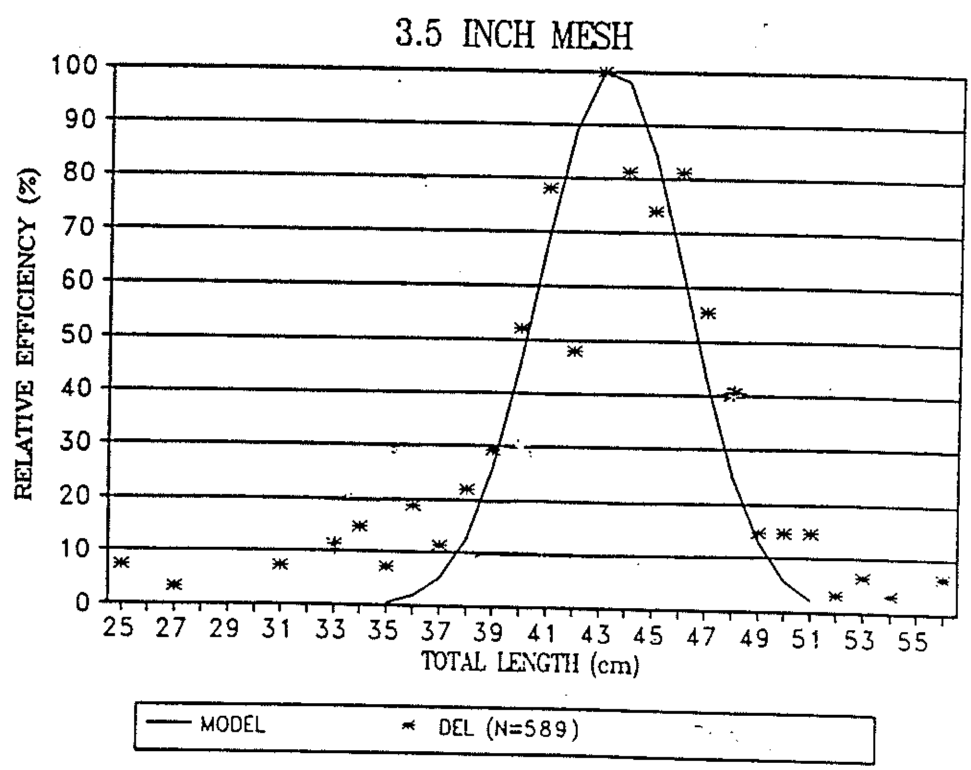
(d)


3.125 INCH MESH
RELATIVE EFFICIENCY (%)
0
10
20
30
40
50
60
70
80
90
100
25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
TOTAL LENGTH (cm)
MODEL
NC SINK (N=233)
DEL (N=173)

(e)


3.25 INCH MESH
100
90
80
70
60
50
40
30
20
10
0
RELATIVE EFFICIENCY (%)
25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67
TOTAL LENGTH (cm)
MODEL
DEL (N=589)

(f)


3.5 INCH MESH
100
90
80
70
60
50
40
30
20
10
0
RELATIVE EFFICIENCY (%)
25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55
TOTAL LENGTH (cm)
MODEL
DEL (N=589)

(g)

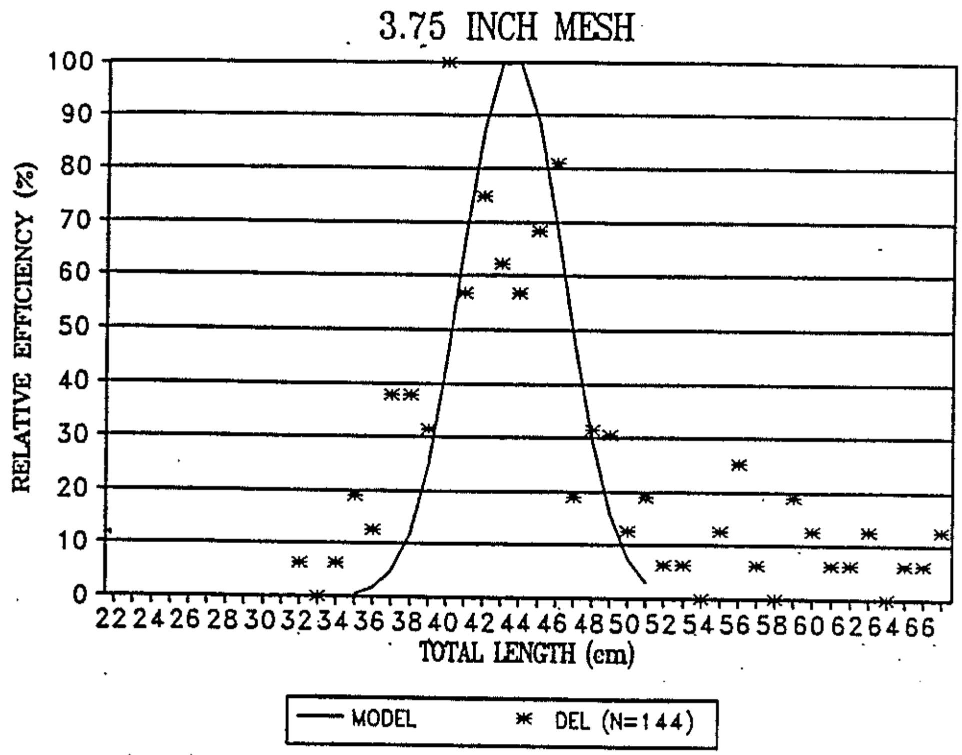

3.75 INCH MESH
RELATIVE EFFICIENCY (%)
0
10
20
30
40
50
60
70
80
90
100
22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66
TOTAL LENGTH (cm)
MODEL
DEL (N=144)

Figure 8. The probability of reaching 10% or 20% maximum spawning potential (MSP) in 5 years for various levels of F.

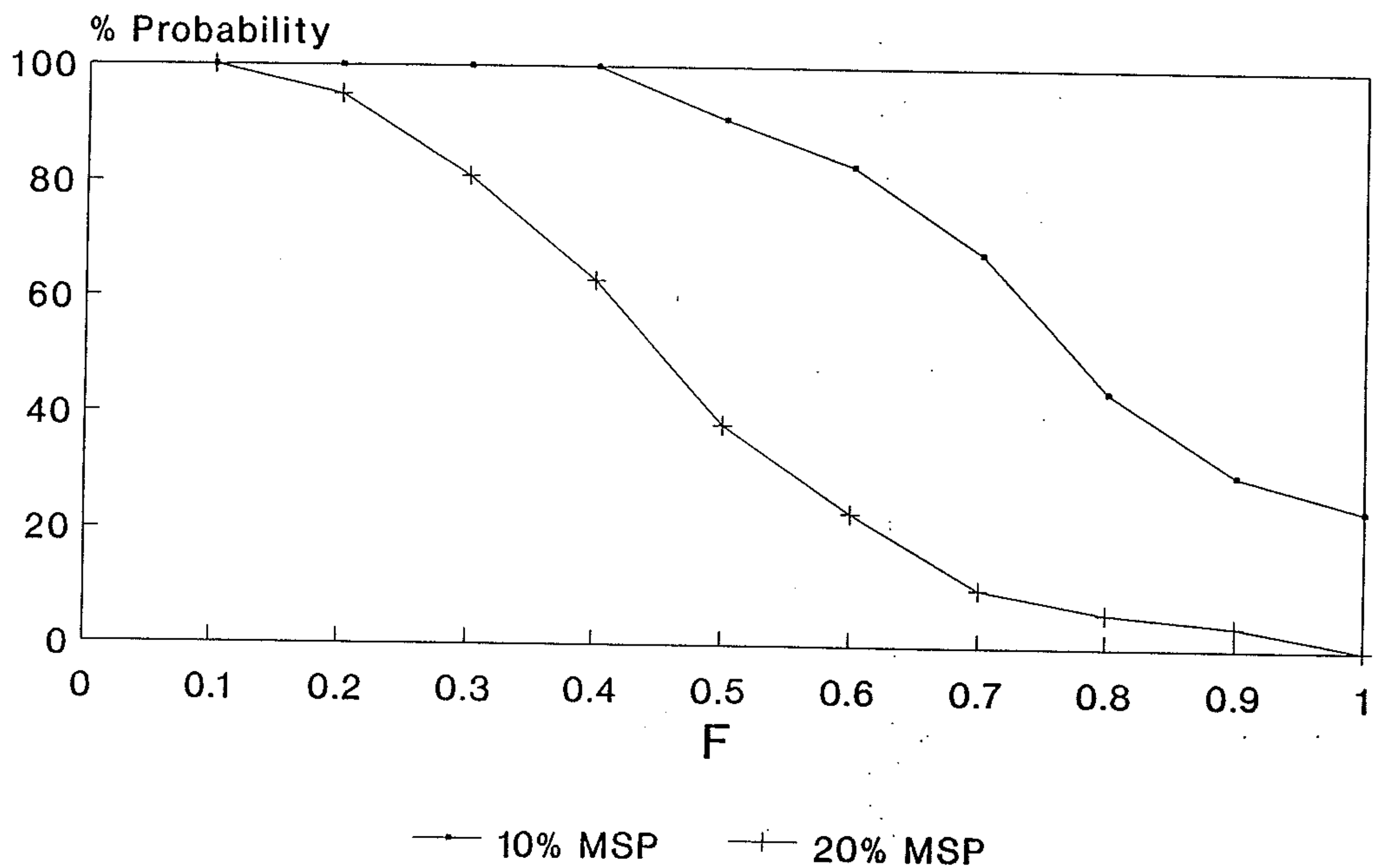


Figure 9. The probability of reaching 10% or 20% maximum spawning potential (MSP) in 10 years for various levels of F.