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Title: Yellowtail Flounder, (Limanda ferruginea), Stock Status 1988: A Revision of Southern New England and Georges Bank Assessments

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Abstract Approval: ______________________

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The 1988 status of yellowtail flounder stocks off the U.S. coast of the Northwest Atlantic is assessed using U.S. and distant water fleet commercial fishery statistics and Northeast Fisheries Center bottom trawl survey data. Assessments of Southern New England and Georges Bank stocks are revised using virtual population analysis of 1970-1986 and 1969-1986 time series, respectively. Methods developed for the preparation of catch-at-age matrices are presented for each component: U.S. commercial landings, U.S. discard, U.S. industrial catch, and foreign catch. Input design and results of yield per recruit analyses and catch and stock size projections through the beginning of 1990 are presented for Southern New England and Georges Bank stocks.

Assessment results indicate dramatic increases in fishing mortality for Southern New England and Georges Bank stocks during the 1980's; stock biomass and spawning stock biomass levels have been severely reduced. Yield per recruit analyses indicate that 1986 levels of fishing mortality far exceeded F_{max} levels for both stocks. Catch and stock size projections for both stocks indicate continued reductions in stock biomass and spawning stock biomass; prospects for stock recovery will depend on improved recruitment and reductions in fishing mortality.

Yellowtail Flounder, *Limanda ferruginea*, Stock Status 1988:

A Revision of

Southern New England and Georges Bank Assessments

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INTRODUCTION

Yellowtail flounder, *Limanda ferruginea*, is a right-handed, small-mouthed, bottom-dwelling flatfish named for the yellowish tinge on the underside of its caudal fin. It ranges from the Gulf of St. Lawrence south to lower Chesapeake Bay (Bigelow and Schroeder 1953), and is generally found at depths of 30 to 70 meters. There are five relatively distinct major areas of concentration within this range: Southern New England, Georges Bank, Cape Cod, Nova Scotia, and the Grand Banks of Newfoundland (Royce et al. 1959, Lux 1963). Off the U.S. coast, smaller concentrations of yellowtail flounder are also found in the Gulf of Maine and in the Middle Atlantic.

Historically, yellowtail flounder has contributed significantly to the demersal component of the New England fishery resource. In New England, it is sought primarily by Massachusetts and Rhode Island otter trawlers in Southern New England and on Georges Bank fishing grounds. Estimated total catch has fluctuated considerably over the past two decades, peaking at 64,100 metric tons (mt) in 1969 (the peak year of exploitation by distant water fleets) before declining to only 11,300 mt in 1978 (Table 1). U.S. landings increased to 33,100 mt by 1983 with recruitment of the 1981 year class, but have since dropped to an all time low of 6,000 mt in 1987.

Significant yellowtail flounder landings in the Northwest Atlantic have originated from concentrations on Southern New England, Georges Bank, Cape Cod, and Middle Atlantic fishing grounds. A smaller fishery has existed historically in the Gulf of Maine (Figure 1). Since 1960, approximately 40% of total U.S. landings have come from Southern New England, 41% from Georges Bank, 9% from Cape Cod, 8% from the Mid-Atlantic and 1% from the Gulf of Maine (NAFO Divisions 5Z E & W of 69° W and Subarea 6, Figure 2). In 1985, a directed fishery for yellowtail on the Grand Banks of Newfoundland also began making significant contributions to total U.S. landings. Landings from the Grand Banks comprised 34% of the U.S. total in 1985, 25% in 1986, and 20% in 1987.

This document presents a current assessment of the New England and Mid-Atlantic yellowtail flounder resource based on analyses of commercial data and NEFC bottom trawl survey data. Virtual population analysis is used to revise the assessments of Southern New England and Georges Bank stocks. The formerly used descriptive approach relies on annual commercial and research survey indices of stock abundance. Results of the virtual population analyses presented estimate fishing mortality and stock abundance in absolute terms. Methodology and results of yield per recruit analyses for both these major stocks are presented; as are results for a series of catch and stock size projections through the beginning of 1990.

LITERATURE REVIEW

An Intensive study of the yellowtail flounder was undertaken in 1942 when total U.S. landings peaked at 31,500 mt; the study continued through 1947 (Royce et al. 1959). By 1944 a decline had begun in the fishery, reducing annual average landings to 7,600 mt during the mid-1950's. The decline and continued scarcity of the yellowtail caused consternation within the industry, particularly as it recalled the effects of decreased populations of winter flounder, Pseudopluronectes americanus, in the early and middle thirties; that species had yet to recover as late as 1951. Royce et al. (1959) contended that the decline in yellowtail flounder populations was not caused by over fishing, although this may have decelerated the rate of recovery, but asserted that the change may be associated with fundamental ecological changes, e.g., a warming of the climate. They further saw no evidence of a significant waste of small fish during the periods of their study and, therefore, concluded that no restrictive legislation appeared necessary unless there was a radical change in the conduct of the fishery.

In 1961, distant water fleets (primarily U.S.S.R.) began to fish Atlantic herring on Georges Bank, and in the course of this activity discovered large groundfish stocks. Subsequent fishing effort was directed towards groundfish in the mid 1960's, which resulted in a peak yellowtail catch of 57,000 mt in 1969; 20,700 mt of which were taken by foreign harvesters in that year (Clark et al. 1981). Thereafter, landings again decreased steadily to only 11,300 mt in 1978 and have since not shown any substantial increase. The population seems to have stabilized at this low level of abundance.

Lux conducted basic research on yellowtail flounder during the 1960's to: 1) identify groups in New England (Lux 1963), 2) determine length-weight relationships (Lux 1969a), and 3) develop techniques for calculating CPUE and total mortality rates (Lux 1969b). Lux and Nichy (1969) estimated von Bertalanfy growth coefficients for yellowtail. They found that length at age, as determined from scales, differed slightly on the three New England fishing grounds examined: New England, Georges Bank, and Cape Cod.

Brown and Hennemuth (1971) developed a method for predicting yellowtail population size from pre-recruit catches; this method has since been used in analysis of the Southern New England fishery population. In 1972 an annual series of yellowtail flounder assessment documents was also begun, these NEFC Woods Hole Laboratory Reference Documents report the current status of the stocks.

Pentilla and Brown (1973) used four different procedures on survey data from 1963 to 1969 to estimate total mortality rates for yellowtail from survey cruise data for Southern New England and Georges Bank areas. Each method showed a lower mortality rate for Georges Bank than for Southern New England, with an average of the estimates giving Z = 1.00 and Z = 1.23 for each area, respectively.

During the mid 1970's Sissenwine concentrated his research activities on questions surrounding the dynamics of the Southern New England yellowtail population. Sissenwine (1975) investigated the relationship between growth and temperature. He used Kendall rank correlation coefficients of the annual average air temperature at Block Island, R.I. with the annual average growth per fish for 1944-1965 and with K for 1962-1970 and found a negative correlation at the 1% level of significance. Sissenwine (1977) also developed a compartmentalized simulation model that considered both linear and density independent relationships between stock and recruitment. This was a successful attempt to demonstrate that the parameters and relationships determined for the Southern New England yellowtail flounder fishery were realistic, and to demonstrate the usefulness of models for predicting a fishery. Sissenwine and Bowman (1978) also looked into some factors affecting the catchability of fish by bottom trawls. The diurnal difference was approximately 5 times greater for nighttime over daytime catches. This difference is dramatic and raises several questions regarding yellowtail behavior with respect to the catchability of this species by survey trawls.

Parrack (1976 MS) attempted virtual population analysis of the Georges Bank yellowtail flounder stock; his catch-at-age matrix covered the 1963-1975 period. Parrack estimated that during the 1963-1973 period the adult stock varied between 44-85 million fish averaging 67 million; stock size fell to time series lows of 42 million in 1974 and 34 million in 1975. Parrack concluded: "These low abundances are the result of a trend of decreasing abundance of incoming cohorts since 1971 and high fishing mortality in 1973, 1974, and 1975. The 1971 year class is apparently but 60% as large as the average of the previous nine cohorts; it is but one-half the size of the 1965-1967 cohorts. Estimates of the stock size of the 1972-1974 cohorts at age one indicate that they are not unusually abundant so that a continuing trend of high F's will further reduce the stock."

Howell and Kesler (1977) analyzed the fecundity of the Southern New England population of yellowtail flounder. Howell (1980) examined temperature effects on growth and yolk utilization in yellowtail flounder yolk-sac larvae. He determined that sea temperatures between 8^{o}C and 12^{o}C would have little, if any, differential effect on larval size at yolk-sac absorption and, therefore, on ability to survive. It also appeared that 4^{o}C was at or near the lower thermal limit for successful reproduction of Southern New England yellowtail founder.

Borden and Fogarty (1980) assessed the distribution and relative abundance of Southern New England yellowtail flounder. This research represented the efforts of a consortium of state, federal, and private organizations combined in an attempt to clarify the status of the resource. The Rhode Island Division of Fish and Wildlife, in conjunction with the Pt. Judith Fishermen's Cooperative, the New Bedford Seafood Council, Inc., the New England Regional Fishery Management Council, and the Northeast Fisheries Center agreed to jointly conduct a yellowtail flounder survey utilizing a commercial vessel.

Morse and Morris (1981) investigated the lengths at maturity of yellowtail occurring west and south of the Long Island group and its relationship to the groups identified by Royce et al. (1959)| 1) off eastern Long Island, 2) Georges Bank, 3) off the tip of Cape Cod northward along the Massachusetts coast.

Collie and Sissenwine (1983) developed a modified Delury method to estimate fish population size from relative abundance data. The technique estimates catchability coefficients, and accounts for error in the measurement of relative abundance. The technique is demonstrated using NEFC Georges Bank and Southern New England yellowtail flounder bottom trawl survey data as a measure of relative abundance.

O'Brien and Mayo (1984) examined variations in catch per unit effort (CPUE) for the yellowtail flounder fishery from 1964-1983 by statistical area, vessel size, depth, and time. A basis was provided for computing fishing power coefficients which better represented the current vessel composition of the yellowtail fleet. Results showed significant changes in CPUE from the time when Lux (1964) set the original standards. Revisions were made in fishing power coefficients and CPUE calculations which reflected the tonnage class of vessels and geographic regions associated with the fishery.

Moseley (1986) compared male and female yellowtail flounder growth between Southern New England, Georges Bank, Cape Cod, and Middle Atlantic fishing areas. He found significantly different mean lengths at age among these four areas and between the sexes within each area. Georges Bank fish were the largest at ages 1, 2 and 3 followed by those from Southern New England, Cape Cod and the Middle Atlantic. Cape Cod flounder were the largest at ages 4 and older, followed by those from Georges Bank, Southern New England, and Middle Atlantic. Females were significantly larger at ages 2 and older within every area except Cape Cod.

A key source of information on yellowtail is represented by the limited circulation or "gray" literature generated by the Northeast Fisheries Center. This literature has been presented in the form of annual Laboratory Reference Documents, or since 1980 as an annual NOAA Technical Memorandum, "Status of the Fishery Resources Off the Northeastern United States". These documents form the backbone of research on yellowtail flounder, as they present the analyses, summary and biological interpretation of nearly all research and commercial data collections. Prior to the Magnuson Fishery Conservation and Management Act (MFCMA 1976), when the United States was still a member of the International Commission for the Northwest Atlantic Fisheries (ICNAF), the above mentioned assessment documents were published as ICNAF Research Documents and were circulated internationally.

Gulland (1965) introduced virtual population analysis (VPA) as a useful assessment technique. The method enables estimates of population at age and fishing mortality to be made independently of the measurement of effort. Pope (1972) investigated the accuracy of virtual population analysis asking the question: What causes the various errors and how can their magnitude be calculated?

Pope (1972) published his work investigating the accuracy of virtual population analysis using cohort analysis as a simplified approximation of Gulland's method. The simplicity of cohort analysis made it possible to investigate the errors generated in such estimates by the arbitrary choice of the rate of fishing mortality on the last age exploited and by the sampling errors of the catch-at-age data.

Agger et al. (1971), Ulltang (1977), and Sims (1982; 1984) investigated various sources of error and developed techniques to measure their effects on VPA (cohort analysis) stock size estimates. Among the sources of error investigated were: 1) unevenly distributed catches, 2) sampling error, 3) error in the estimation of natural mortality, 4) error in the estimation of fishing mortality during the terminal year of an analysis, 5) the effects of seasonal variations in stock size, and 6) stock migrations.

Pope and Shepherd (1982) developed a simple algorithm for the preparation of VPA's commonly referred to as the separable VPA (SVPA). The SVPA allows for internal consistency by assuming a constant exploitation pattern. The method reduces trial and error in the preparation of VPA's and reduces the number of parameter estimates required. Shepherd and Stevens (1983) published a separable VPA users guide.

Pope and Shepherd (1985) presented a comparative study of various VPA tuning methods using various sets of simulated data. As a result of their tests a new hybrid method was developed and tested.

OBJECTIVE

1. The primary objective of this research was to revise assessments of the Southern New England and Georges Bank yellowtail flounder stocks to analytical status using the technique of virtual population analysis. And, to thereby examine historical levels of fishing mortality and stock size in more absolute terms towards the goal of their more rational exploitation.

   In order to accomplish this objective, the following steps were taken:

2. A systematic method was developed for estimating numbers of yellowtail flounder discarded in the U.S. commercial fishery. This method presents an alternative to estimates based solely on the proration of reported discard levels obtained from a sampling of landed commercial vessels.

3. Methods were developed for estimating numbers-at-age of yellowtail flounder caught by foreign nations.

4. A method was developed for estimating numbers-at-age of yellowtail flounder caught in the U.S. industrial fishery.

MANAGEMENT

The New England yellowtail flounder fishery was managed by the International Commission for the Northwest Atlantic Fisheries (ICNAF) from 1971 through 1976. It was then managed by the New England Fishery Management Council (NEFMC) under the Fishery Management Plan (FMP) for Atlantic Groundfish (as amended) from March 15, 1977 until March 30, 1982. Management was by calendar year until October of 1978 and subsequently by fishing year (October 1-December 30) until early 1982. Management provisions of the Plan included: 1) the establishment of optimum yield (OY) levels, 2) minimum cod end mesh size regulations, 3) trip limits, 4) spawning area closures, and 5) data reporting requirements. Optimum yield levels for both management units (east and west of 69° W longitude) were set at 5,000 mt for 1980 and 1981. A summary of calendar and fishing year OY's implemented under the FMP during 1977-1981 is given in Clark et al. (1981).

Attempts to restrict harvests to these levels in New England's mixed groundfish fishery led to a complex series of regulations which were ignored or circumvented in many cases, and seriously impaired the reliability of the commercial data base. In response to these and other problems, the NEFMC began developing the Atlantic Demersal Finfish Plan (ADF) for the cod-haddock-yellowtail groundfish complex (legislated in 1981), to better address mixed species management problems in New England groundfish fisheries.

While the ADF was being developed and Interim Fishery Management Plan was implemented and became effective on March 31, 1982. The Interim Plan redefined OY as the amount of yellowtail flounder actually harvested by U.S. fisheries in accordance with other plan provisions, which included: 1) mesh regulations by area, 2) a minimum possession size of 28 cm (11 inches) for yellowtail, and 3) a voluntary data reporting system. A large mesh area was established, including shoreward portions of the Gulf of Maine west of Penobscot Bay and Georges Bank, where vessels using trawl gear were required to use cod ends with stretched mesh sizes measuring at least 130 mm (5 1/8 inches) during the first year of the Interim Plan, and 140 mm (5 1/2 inches) the next.

There was also an Optional Settlement Program under the Interim Plan, within which the Regional Director could sanction the legitimate prosecution of small mesh fisheries within the large mesh area. Only a small percentage of groundfish permit holders were ever licensed to participate in this program.

The Atlantic Demersal Finfish Plan was renamed the Northeast Multi-species Fishery Management Plan and was conditionally approved by NMFS on July 17, 1986. Yellowtail flounder is currently managed under Amendment #1 to the Northeast Multi-species FMP; regulations became effective on September 15, 1986. Amendment #2 is currently under development by the New England Fishery Management Council.

Regulatory measures under Amendment #1 include: 1) non-possession within the Exclusive Economic Zone (EEZ) of a minimum commercial size for yellowtail established at 12 inches; recreational fishermen are not subject to a minimum size requirements, 2) 5 1/2 inch regulated minimum mesh size for mobile gear; and, 3) seasonal areal closures for portions of the New England/Mid-Atlantic area west of 69°40" longitude, to provide reduced mortality and enhanced spawning opportunity.

SOUTHERN NEW ENGLAND

COMMERCIAL LANDINGS

Distinct peaks in total catch are evident for the Southern New England grounds during the 1940's and 1960's (Table 1, Figure 4). The fishery collapsed during the early-to-mid 1970's; landings fell as low as 1,600 mt in 1976. Subsequently, reported annual landings increased to an annual average of 5,400 mt during 1979-1981. Under the Interim Plan, landings had increased to 17,900 mt by 1983. Landings have since declined to an average of 3,200 mt during 1985-1986, 68% lower than the 1960-1984 average. Total U.S. landings in 1987 were 1,600 mt, 52% lower than in 1986; representing the lowest annual yield since 1976. Commercial effort (24 hour days fished) also decreased 52% from 1986. As is traditional, otter trawls accounted for 93% of the yellowtail landed in 1987; the remaining 7% were taken by scallop dredges.

The Southern New England industrial fishery for yellowtail flounder was conducted primarily out of Point Judith during the 1950's and 1960's. After 1973, the annual industrial catch did not exceed 100 mt.

CATCH COMPOSITION

Sampling Intensity - Southern New England length frequency samples averaged 1 per 148 mt landed during the 17 year time period; it was lowest during the early 1980's, averaging 1 sample per 264 mt during 1981-1983. It improved to 1 sample per 66 mt during 1985-1986. The level of age sampling is generally reflected by that of the length sampling.

Construction of Catch-at-Age Matrix - Preparation of the 1970-1986 catch-at-age matrix for Southern New England required development of the methodology, computation, and compilation of estimates from four data sources: 1) biostatistics of U.S. commercial landings, 2) U.S. commercial discard, 3) the U.S. industrial fishery, and 4) catch by foreign nationals. Numbers in each component of the catch-at-age matrix (1970-1986) are presented in Table 8.

Estimates of U.S. landings at age during 1970-1986 were made using NEFC's biostat program, written by Hauser in 1985. The biostat program allows landed weights to be expressed as numbers of fish in each length and age category. Market categories (small, large, and unclassified) were combined, and monthly totals of age and length samples were pooled by calendar quarter for each year.

The chronology of mesh size regulations in effect under ICNAF, MFCMA, and the Interim Plan (of the Atlantic Demersal Finfish Plan) management regimes was used in conjunction with size selection curves for yellowtail flounder (Smolowitz 1983) to estimate annual percent retention at length. These estimates of lengths retained in commercial catches using the prescribed mesh size were then apportioned into numbers marketed or discarded using: 1) percentages at length in the population as reflected by NEFC bottom trawl survey data, 2) cull points as reflected through commercial length samples of yellowtail landed in the 'small' market category (Table 6), and 3) respective NEFC bottom trawl survey age/length keys. A summary of numbers discarded is presented in Table 11. Estimated numbers landed at age were then increased by the percentage of total U.S. catch estimated to have been discarded (Table 7).

Industrial length samples were applied to metric tons of industrial catch per year as estimated in previous yellowtail assessments, e.g., McBride and Clark (1983). Average weights from these samples were used to estimate total catch in numbers. Survey age/length keys were used to apportion numbers at age.

Estimates of foreign catch (mt) were obtained from ICNAF and NAFO Statistical Bulletins. Nominal catches by Eastern Block countries (primarily U.S.S.R., Rumania, Bulgaria) and Japan were almost exclusively taken by small mesh gear, i.e., trawls with 40-mm mesh codend liners (Clark et al. 1982). The 25 mm codend mesh normally used in the industrial fishery (Brown and Hennemuth 1971) was assumed to have similar retention qualities as a 40-mm mesh. Thus, average weights from the industrial samples were used to estimate numbers caught by these countries, and to apportion the numbers at length. Canada was assumed to have upheld prevailing international mesh regulations; numbers and lengths retained were estimated by methods similar to those used in the United States. Spring and Autumn NEFC survey age/length keys were combined annually to estimate catch-at-age.

Mean Weight-at-Age Matrix - A mean weight-at-age matrix (Table 10) covering ages 1-8+ at the beginning of each year for the Southern New England fishery (1970-1986) was constructed using average weight (kg) estimates for quarter 1 generated by NEFC's biostat program. Age 1 fish are generally not landed commercially before quarter 4. Estimates of quarter 1 mean weights-at-age were obtained by forming ratios of survey mean lengths at ages 1 and 2 to biostat mean weight at age 2.

Minimal yearly variations were apparent for ages supporting the bulk of the catch. Significant variations may occur in pre-recruit or older ages due to small sample size. A small number of gaps were estimated through interpolation or averaging under the advisement of Judy Pentilla (Chief Fishery Biology Investigation, NEFC Woods Hole, and senior age reader for yellowtail flounder).

STOCK ABUNDANCE AND BIOMASS INDICES

Commercial Catch Rates - Commercial catch per unit effort (CPUE) indices through 1984 were calculated for domestic trawlers using trip data for vessels of 5-104 gross registered tons (GRT), for which at least 50% of the total catch by weight consisted of yellowtail flounder (Lux 1964). These calculations involved standardization of fishing effort by applying fishing power coefficients to summarized vessel class effort data (24 hour days fished) using 26-50 GRT vessels as the standard. Adjusted effort data were then summed over vessel classes and divided into corresponding landings plus discard estimates to obtain CPUE indices (catch per day fished in thousands of metric tons) for the Southern New England, Georges Bank and Cape Cod grounds (Table 3).

The average CPUE for Southern New England from 1960-1986 is 2.79 thousand mt/day fished. The index peaked in 1964 at 5.6 thousand mt/day fished. Values since have decreased gradually to 1.2 thousand mt/day fished in 1976, increased to 3.6 thousand mt/day fished in 1982 with increased availability after a brief period of improved recruitment, and have subsequently declined to time series lows averaging 0.8 thousand mt/day fished during 1985-1987.

Research Vessel Survey Indices - NEFC has conducted stratified random bottom trawl surveys in offshore waters (greater than 27 m) of the northwest Atlantic in autumn since 1963, and in spring since 1968. A "36 Yankee" trawl has been used in all autumn surveys and in all spring surveys except during 1973-1981 when a modified high-opening "41 Yankee" trawl was used. Both trawls are equipped with roller gear and 1.25-cm (0.5-inch) codend liners. Conversion factors have been applied to spring survey catch-per-tow data to adjust for differences in fishing power between these trawls (Sissenwine and Bowman 1978). Further information on NEFC survey design, procedures and the application of resulting data to yellowtail assessments is provided in Azarovitz (1981), Clark et al. (1982), and McBride and Clark (1983).

The late 1960's marked the beginning of a period of pronounced decline in abundance and biomass for Southern New England yellowtail flounder (Table 14, Figure 10). By 1975, the autumn abundance index had fallen 93% below the 1963-1974 average; the biomass index fell 94% below. The late 1970's and early 1980's showed signs of stock recovery, with improved recruitment. Autumn number per tow at age 2 in 1982 was the highest observed since 1967. Since 1983, however, total indices of abundance and biomass have declined dramatically, 1987 being near the lowest in the time series. Indices for the spring survey generally show similar trends in both abundance and biomass; fundamentally one of dramatic overall decline. The 1987 NEFC offshore autumn survey indices decreased from 1986 in both total abundance (-14%) and biomass (-31%); indices are 89% and 92% below the 1963-1986 time series averages, respectively (Table 5). Spring and autumn indices appear somewhat inconsistent; at such low levels of abundance small changes appear large and, thereby, become difficult to interpret.

MORTALITY

Natural Mortality - Instantaneous natural mortality (M) for Southern New England was assumed to equal 0.2 (Lux 1969b).

Total Mortality - Pooled estimates of instantaneous total mortality (Z) for Southern New England were obtained using NEFC autumn and spring offshore research vessel survey catch-per-tow at age data for Southern New England. Estimates of Z were calculated for fully recruited age groups for periods when yellowtail was under differing management regimes 1970-1976 (ICNAF), 1977-1981 (MFCMA), 1982-1986 (Interim Plan) and 1987 (Multi-species FMP) using the following relationships, with 1970-1976 as an example:

AUTUMN: ln (Σ age 2+ for 1969-75/ Σ age 3+ for 1970-76)

SPRING: ln (Σ age 3+ for 1970-76/ Σ age 4+ for 1971-77)

These data have not been biased by discard or reporting uncertainties; therefore results would appear more reliable.

Calculated Z values are as follows:

	AUTUMN	SPRING	GEOMETRIC MEAN
1970-1976	0.50	1.06	0.73
1977-1981	1.30	0.68	0.94
1982-1986	1.28	2.08	1.63
1984	2.02	2.25	2.13

Different age groups were used in the autumn and spring analyses so that Z could be evaluated over identical year classes within each time period.

Pooled estimates of spring and autumn survey data have not been entirely consistent in their depiction of mortality trends. Rather than selecting one survey series over the other, total mortality was calculated by taking the geometric mean of the spring and autumn estimates for each time period.

The trend in fishing mortality has been high and increasing throughout the time series. The highest F was observed in 1984. Improved recruitment in the early 1980's resulted in a period of intense effort and higher CPUE; 1983 catch represented the highest since 1970. Effort remained high (Table 3) although recruitment declined dramatically (84%, Table 14, Figure 12) after the 1981 year class entered the fishery.

ESTIMATION OF STOCK SIZE

Virtual Population Analysis - A partial recruitment vector for 1986, was estimated through the use of separable VPA (Pope and Shepherd 1982). Tests runs were made with F = 0.5-2.0 and S (F on the oldest age relative to that on the reference age, on average) = 1.0. The full catch matrix (ages 1-8+, Table 8) was used, and 3 was used as reference age (Anonymous 1983; Shepherd and Stevens 1983).

Age specific exploitation patterns of partial recruitment vectors were very similar irrespective of input F. Coefficients of variation were near equal (ranging from 41.7-41.9). Using the residual table as a guide to suitability (ICES Working Group Report C.M.1983/Asses:17), a few relativity large log catch ratio residuals were found primarily in age 1's or in ages older than which constitute the bulk of the catch. The resulting SVPA partial recruitment vector was:

	AGE							
	1	2	3	4	5	6	7	8+
S(j)	0.0212	0.4376	1.0000	1.0384	1.1683	1.2262	1.0000	1.0000

As a directional tool in finding a reasonable value for terminal F, 1986 point estimates of F were calculated using survey data. Preliminary linear regressions (simple) through 1983 (3 years allowed for convergence), full time series linear regressions, and regressions forced through the origin were run using SVPA output to find the best variables for estimating terminal F. The smoothed weight per tow autumn survey index (independent variable, Fogarty et al. 1986) vs. SVPA total weight estimate (dependent variable) surfaced as the best combination for Southern New England using a simple linear regression. A summary of calibration criteria for selecting terminal F and tuning results is presented in Table 13.

Virtual population analysis (VPA) was conducted using 1970-1986 catch-at-age and mean weight-at-age matrices (Tables 8 & 10, respectively). F = 1.4 was the optimal terminal F value determined for 1986. Results indicate that F levels: 1) averaged 0.69 during 1970-1973, 2) increased significantly to exceed 1.0 during 1974-1975, 3) fluctuated below 1.0 during the late 1970's, and 4) have risen above and remained well over 1.0 during the 1980's, peaking at 1.9 in 1984 (Table 14, Figure 9).

Spawning stock biomass (SSB) declined 92% during the entire time series to an absolute low in 1985 (3,200 mt, Table 14, Figure 10). An improving trend during the early 1980's resulted in 1983 having the largest SSB since 1972 (and the largest landings since 1968, whereas SSB in 1983 was 43% below the 1970 estimate, 1968 value not available); 1984 SSB dropped 55%, and then another 67% from the 1984 value by 1985. Estimated SSB for 1987 was slightly larger than for 1986; however, it remained 68% below the time series average.

Generally, VPA trends in fishing mortality and stock biomass (SB) agree with those derived from NEFC bottom trawl survey (Tables 4 & 14), and commercial CPUE indices (Table 3). Overall trends in abundance at ages 1 and 2 as reflected by VPA stock size numbers and by NEFC survey stratified mean number per tow indices are supportive (Figures 12-15).

YIELD PER RECRUIT ANALYSIS

Yield and spawning stock biomass per recruit analyses were conducted for Southern New England using the Thompson and Bell (1934) algorithm to sum yields from age groups 1 through 8+ (Table 16). The partial recruitment (S(j)) vector from the SVPA was used as fishing mortality pattern. Instantaneous natural mortality was again assumed to be 0.2 (Lux 1969b). The maturity ogive for females used was determined from maturity observations collected from Cape Hatteras, North Carolina to Nova Scotia in 1977 (Morse 1979, Gabriel 1985).

Both commercial and survey age sampling inadequacies were encountered during the approximate time of peak spawning. Therefore, annual weights at age for commercial landings during 1983-1986 were averaged and used to represent mean weights in both catch and stock. Thus, spawning stock biomass per recruit estimates may have a slight upward bias, reflecting growth between peak spawning and the end of the calendar year. This bias might be offset to a significant degree by increased gonad weight during time of peak spawning.

Results of this analysis (Table 16, Figure 20) indicate that $F_{0.1}$ = 0.210 and F_{max} = 0.545. The VPA estimate of F in 1986 is 1.48, 7 times larger than $F_{0.1}$ and nearly 3 times larger than F_{max}. Relative to F_{max}, the 1986 F would generate approximately 35% less stock biomass (yield) per recruit and 60% less spawning stock biomass per recruit under equilibrium conditions.

CATCH AND STOCK SIZE PROJECTIONS

Catch, total stock biomass, and spawning stock biomass were projected for Southern New England through 1989 (i.e., to the beginning of 1990) using NEFC's catch and stock size prediction program as written by Mayo in 1974; this technique is based on a generalization of the Murphy catch equation (Tomlinson 1970). Projections were based on estimated 1987 stock size; predicted recruitment of the 1986 year class in 1987 was estimated to be 15.5 million fish. This represents a 13% increase over estimated age 1 recruits in 1986, and can be regarded as very optimistic considering the recent history of the stock. Thus, two sets of projections were made: 1) Projection A averages the last 3 estimates in the VPA time series, assuming 1988-1990 average recruitment at age 1 to be 13.4 million fish, and 2) Projection B averages the 3 lowest recruitment estimates in the time series (1973, 1974 & 1983), assuming 1988-1990 recruitment to be 7.8 million fish.

Averaged (1983-1986) quarter 1 commercial mean weights at age were used for stock projections (age 1 as estimated for mean weight-at-age matrix). Averages (1983-1986) of annual commercial mean weights at age were used to estimate catch (patterns thought to be unreasonable due to sampling inadequacies for quarter 1 (ages 6-8+) were prorated using annual weight-at-age patterns). Fishing mortality selection coefficients for ages 1 and 2 were set at 1983-1986 weighted means of partial recruitment values generated through VPA (age 1 = 0.0319, age 2 = 0.4402).

SVPA partial recruitment estimates for fully recruited ages (3+) tended to exceed 1, these estimates were used in the VPA as they represent a 17 year historical analysis. Considering the futuristic nature of catch and stock size projections, however, fishing mortality selection coefficients at fully recruited ages (3+) were set at 100% of the F level being evaluated. Results and data used in projections are summarized in Tables 18 & 19.

The number of 24-hour commercial days fished in Southern New England dropped 52% from 1986 to 1987; landings also dropped 52%. The estimated fishing mortality for 1987 (0.475) corresponds to 1987 reported landings; this value is below the estimated F_{max} (0.545).

Projection A - Fishing mortality in 1988 was set at 0.175 corresponding to reported 1988 U.S. landings (approximately 903 mt). At the beginning of 1989, SB is projected to be 10,915 mt and SSB 8,087 mt, representing 26% and 39% increases in SB and SSB, respectively, over the beginning of 1988. Options considered for F in 1989 were: 1) F89 = F88, 2) F89 = $F_{0.1}$ (0.210), 3) F89 = F_{max} (0.545), and 4) F89 = a range of levels from 0.1-2.0.

Under Option 1, estimated catch in 1989 would be 1,270 mt; SB at the beginning of 1990 would be 12,738 mt, and SSB 9,958 mt. This represents a 41% catch increase over the reported 1988 landings; SB and SSB show 17% and 23% increases, respectively, by the beginning of 1990. SB and SSB both show some increase through F = 0.4. If increased as high as F_{max} (0.545, Option 3), however, SB and SSB levels show decreasing trends; stock maintenance might only be achieved through above average recruitment. If F were increased to 1.0 in 1989, SB at the beginning of 1990 will have decreased 23% and SSB 29% from the levels predicted if F89 = F88.

Projection B - At this more conservative estimate of recruitment in 1988-1989 and with F89 = 0.175, SB at the beginning of 1990 would be 9,969 mt and SSB 8,360 mt (22% & 16% below Projection A estimates, respectively). If F89 were increased above the 1988 level (0.175), stock abundance would also be expected to decrease below the 1988 level. Considering the recent history of the stock, this projection would also appear to be optimistic. If the estimate of 1987 recruitment was too high, estimates of 1988 fishing mortality at the given catch level, may be too low.

DISCUSSION

Results from this assessment indicate that fishing mortality levels for the Southern New England yellowtail flounder stock have undergone significant increases; levels during the 1980's have been very high while spawning stock biomass is very low. Significant reductions from the levels of the past few years would be needed to rebuild this stock.

A reduction in effort and fishing mortality since 1986 is apparent through reported landings. Total U.S. landings in 1987 were

1,600 mt, 52% lower than in 1986 and representing the lowest annual yield since 1976. Commercial effort (24 hour days fished) also decreased 52% from 1986. This reduction was probably the result of stock biomass being too low to support a directed fishery; even with the significant increase in recruitment at age 1 stock biomass in 1987 remained 62% below the time series average.

Reduced effort over a sustained period might produce more favorable conditions for improvements in stock abundance and biomass. A 14% increase in the estimated number of age 1's in 1987 remains 40% lower than the 1970-1986 average.

GEORGES BANK

COMMERCIAL LANDINGS

Reported landings from Georges Bank fluctuated about an average of 14,000 mt from the mid-1960's through the early 1970's before declining to only 4,500 mt in 1978 (Table 1). Subsequent landings increased to an annual average of 11,000 mt during 1982-1983, but again declined during 1985-1987 to reach historic lows averaging 2,700 mt annually. Landings in 1987 (2,700 mt) declined 10% from 1986; CPUE declined 15%. The projected total for 1988 is 1,800 mt, 40% below that of 1987 (2,700 mt). Again, increased landings during 1982-1983 resulted from improved recruitment of the 1979-1981 year classes. The fishery began its current trend of decline in 1984. It has become heavily dependent upon incoming recruitment. Increased landings and CPUE occurred during the final calendar quarter of 1986 in response to recruitment of the 1984 year class, however, the year class was not a strong one and no longer sustains elevated landings.

Holding with tradition, 97% of yellowtail landed from Georges bank were taken with otter trawls; the remaining 3% were taken with scallop gear.

CATCH COMPOSITION

Sampling Intensity - Georges Bank length frequency sampling averaged 1 sample per 168 mt landed during the 18 year time series; it was lower during the early 1980's (averaging 1 sample per 244 mt during 1980-1983). But, improved to 1 sample per 103 mt during 1984-1986. The level of age sampling is generally reflected by that of the length sampling.

Construction of Catch-at-Age Matrix - The catch-at-age matrix for Georges Bank was constructed using similar methods as for Southern New England; 1969 estimates are also included. Estimates are included for a minimal Canadian effort which Georges Bank supported through 1973. Canada was assumed to have adhered to U.S. management regulations (Richard Hennemuth, NEFC Woods Hole Laboratory Director, personal communication). Canadian catch estimates are as reported in NAFO circular letters; U.S. commercial catch-at-age percentages were used to apportion Canadian totals. Industrial landings were not reported on Georges Bank, and so were not included in the catch estimation procedure. Catch-at-age (numbers) for each component of the Georges Bank fishery (1969-1986) are presented in Table 9.

Mean Weight-at-Age Matrix - The mean weight-at-age matrix for Georges Bank was constructed using the same methods as for Southern New England; estimates for 1969 were included (Table 10).

STOCK ABUNDANCE AND BIOMASS INDICES

Commercial Catch Rates - An updated standardization procedure for computing fishing power coefficients better representing the current vessel size composition of the yellowtail fleet has been implemented (O'Brien and Mayo 1984). Catch per day fished estimates for Georges Bank subsequent to 1984 incorporate 73-104 GRT sized vessels as the standard, and include 24-310 GRT as the range of sizes in the fishery (Table 3, Figure 4, Lux 1969b).

The average CPUE for Georges Bank from 1960 through 1986 is 2.55 thousand mt/day fished. The index peaked in 1964 reaching 5.6 thousand mt/day fished. Values since have decreased gradually to 1.4 thousand mt/day fished during 1977-1978, increased to 2.2 thousand mt/day fished during 1982-1983 with improved availability after a brief period of good recruitment, and have subsequently declined to all time lows averaging 0.8 thousand mt/day fished during 1985-1987.

Research Vessel Survey Indices - NEFC catch per tow indices for spring and autumn surveys on Georges Bank have shown similar trends, generally (Table 5, Figure 5). The magnitude of spring survey indices in both abundance and biomass during the late 1960 's and the early 1970's tended to be significantly higher than the autumn. Surveys generally trended downward after the late 1960's, increasing in both abundance and biomass during the early 1980's with improved recruitment; indices have since declined to record low levels.

Large increases in a single year's number per tow index generally reflect 2-3 years of above average recruitment. Significant numbers of well recruited cohorts have not remained in the population beyond age 6. The fishery has become heavily dependent upon incoming recruitment (Table 2). Generally, yellowtail first spawn between ages 2 and 3 (Royce et al. 1959; Howell and Kesler 1977); fecundity appears to increase with age, but has a recorded maximun at age 7 (Howell and Kesler 1977). Thus, a single well recruited cohort does not remain in the population to make sustained significant contributions to the spawning stock biomass.

MORTALITY

Natural Mortality - Instantaneous natural mortality (M) for Georges Bank was assumed to equal 0.2 (Lux 1969b).

Total Mortality - Pooled estimates of instantaneous total mortality (Z) for Georges Bank were obtained using similar methods as for Southern New England. The first time period is extended to include 1969, as is the catch-at-age matrix. The following relationship was used (with 1969-1976 as an example):

AUTUMN: $\ln(\Sigma \text{ age } 2+ \text{ for } 1968\text{-}75 \,/\, \Sigma \text{ age } 3+ \text{ for } 1969\text{-}76)$

SPRING: $\ln(\Sigma \text{ age } 3+ \text{ for } 1969\text{-}76 \,/\, \Sigma \text{ age } 4+ \text{ for } 1970\text{-}77)$

Estimates of Z are as follows:

	AUTUMN	SPRING	GEOMETRIC MEAN
1969-1976	0.82	1.17	0.98
1977-1981	0.62	1.54	0.98
1982-1986	1.58	1.10	1.32
1984	1.75	2.00	1.87

Different age groups were used in the autumn and spring analyses so that Z could be evaluated over identical year classes within each time period.

Again, there is some inconsistency between spring and autumn estimates. Rather than selecting one survey series over the other, total mortality was calculated by taking the geometric mean of the spring and autumn estimates during each time period.

Pooled estimates again show that fishing mortality has been high and increasing throughout the time series. The highest F was observed in 1984 after the period of improved recruitment in the early 1980's.

ESTIMATION OF STOCK SIZE

Virtual Population Analysis - A partial recruitment vector for the Georges Bank VPA was estimated using the same methods as for

Southern New England with catch-at-age and mean weight-at-age matrices spanning 1969-1986. Age specific exploitation patterns were very similar irrespective of input F (0.5-3.0). Coefficients of variation ranged from 44.0-44.2. Again, using the residual table as a guide to suitability, a few relatively large values occur at age 1 or in ages older than constitute the bulk of the catch. The resulting SVPA partial recruitment vector was:

	AGE							
	1	2	3	4	5	6	7	8+
S(j)	0.0378	0.4919	1.0000	1.2569	1.4679	1.3655	1.0000	1.0000

Point estimates of fishing mortality in 1986 were made using survey indices (as for Southern New England). And, using similar methodology, the smoothed weight per tow autumn survey index (independent, Fogarty et al. 1986) vs. SVPA total weight (dependent) variable combination proved best. Forcing a linear regression through the origin determined 1.0 as optimal terminal F value for 1986 for VPA tuning results (Table 13).

Virtual population analysis results for Georges Bank were similar to those for the Southern New England analysis. F levels averaged 0.7 during 1969-1973, increased significantly to exceed 1.1 during 1974-1975. Fishing mortality averaged 1.0 during 1976-1983. However, as in Southern New England, F peaked dramatically in 1984 at

1.977. Levels have since declined to 1.1 in 1985 and 0.8 in 1986 (Table 15, Figure 9).

Similar to Southern New England, SSB decreased 94% during the course of the entire time series, reaching its absolute low point in 1985 (Table 15, Figure 11). Improved recruitment in the early 1980's led to 1983 having the largest SSB since 1974, however this value remained 23% below the 1969-1982 average. Further decline (8 fold) led to a time series low by 1985. The 1987 estimate shows a 38% increase over 1986, but remains 69% below the time series (1969-1986) average.

Generally, VPA trends in fishing mortality and stock biomass agree with survey indices of abundance (Tables 5 & 15), and commercial CPUE indices (Table 3). Overall trends in abundance at ages 1 and 2 as reflected by VPA stock size numbers and by survey stratified mean number per tow indices are supportive (Figures 16-19).

YIELD PER RECRUIT ANALYSIS

Yield and spawning stock biomass per recruit analyses were conducted for Georges Bank using the Thompson and Bell (1934) algorithm to sum yields from age groups 1 through 8+. Partial recruitment, natural mortality, maturity, and weight-at-age vectors applied were derived using similar methods as for Southern New England (Table 17).

Both commercial and survey age sampling inadequacies were encountered during the time of peak spawning (quarter 2). Therefore, annual weights at age for commercial landings during 1983-1986 were averaged and used as both weight in the catch and weight in stock. Thus, spawning stock biomass per recruit estimates may have a slight upward bias, reflecting growth between time of peak spawning and the end of the calendar year. This bias might be offset to a significant degree by increased gonad weight during time of peak spawning.

Results of the analyses (Table 17, Figure 21) indicate that $F_{0.1}$ = 0.211 and F_{max} = 0.584. The VPA estimate of F in 1986 (0.831) is nearly 3 times greater than $F_{0.1}$, and over 42% greater than F_{max}. Relative to F_{max}, the 1986 F generates approximately 14% less stock biomass (yield) per recruit and 25% less spawning stock biomass per recruit under equilibrium conditions.

CATCH AND STOCK SIZE PROJECTIONS

Catch, total stock biomass, and spawning stock biomass for the Georges Bank stock were projected through 1989 (i.e., to the beginning of 1990) using similar methodology as for the Southern New England stock. Projections were based on the estimated 1987 stock size. Predicted recruitment of the 1986 year class in 1987 was 1.5 million fish, lower than any value in the VPA time series.

Average quarter one commercial mean weights at age (1983-1986) were used for stock projections (age 1 averages estimated as for the mean weight-at-age matrix). Annual averages of commercial weights at age (1983-1986) were used to estimate catch. Patterns thought to be inconsistent due to sampling inadequacies for quarter one (ages 6-8+) were prorated based on annual weight-at-age patterns). Fishing mortality selection coefficients for ages 1 and 2 were set at 1983-1986 weighted means of partial recruitment estimates generated by VPA (age 1 = 0.0446, age 2 = 0.6283). SVPA partial recruitment estimates for fully recruited ages (3+) tended to exceed 1, these estimates were used in the VPA as they represented 18-year historical analyses. Considering the futuristic nature of catch and stock size projections, however, fishing mortality selection coefficients at fully recruited ages were set at 100% of the F level being evaluated. Results are summarized in Tables 20-22.

Estimated fishing mortality in 1987 (0.925, corresponding to reported landings) was 58% greater than F_{max} (0.584). By 1988 the level of fishing mortality had increased to 1.2, corresponding to projections based on reported 1988 landings (discard not included). No instances of good recruitment have occurred since 1986 (1984 year class). However, the VPA estimated number of age 1's in 1985 (1984 year class) was 42% lower than the 1969-1984 average.

Options considered for F in 1989 were: 1) F89 = F88, 2) F89 = $F_{0.1}$, 3) F89 = F_{max}, and 4) F = any of a range of values from 0.2-2.0. Predicted recruitment for 1987 was the lowest in the time series, and 85% lower than the weighted average for 1983-1986 (Projection A, as used in the Southern New England projections). Two additional more conservative sets of projections were made: Projection B, using an average of the three lowest recruitment estimates in the VPA time series for 1989-1990; and Projection C, using the 1987 estimated recruitment for 1989-1990. Survey data in 1988 does not suggest that recruitment on Georges Bank will improve in 1989. If 1988-1989 recruitment remains as depressed as it was in 1987, Projection C would be most realistic.

Projection A - Estimated 1988-1990 average recruitment in this projection is very optimistic (9.6 million fish) relative to recent stock trends. Therefore, even a fishing mortality rate of 1.2 in 1988 would result in a 5% increase in SB by the beginning of 1989. Spawning stock biomass, however, may be reduced 17% (1,987 mt), as the 1984 year class will have undergone significant reductions. If F89 were reduced to F_{max} (0.584, Option 3), SB at the beginning of 1990 may be increased 20% (5,090 mt); SSB might then be increased 31% (3,231 mt) over levels generated when F = 1.2.

Projection B - Averaging the three lowest recruitment estimates in the VPA time series yields 6.3 million fish as estimated recruitment for 1988-1990, a 34% reduction from Projection A. F88 would be increased to 1.25 in order to obtain the 1988 reported catch. If the 1988 catch level remains the same for 1989, fishing mortality will remain very high.

Projection C - With an 85% lowered level of recruitment (1.5 million fish), SB at the beginning of 1989 would be 54% lower than in Projection B (1,218 mt); fishing mortality in 1988 would increase even further (1.3) corresponding to reported annual landings. If F89 = F88, SB at the beginning of 1990 would be 46% lower than in Projection B, and SSB 67% lower. Lowering fishing mortality to F_{max} (0.584, Option 3) in 1989 would allow 41% more SB (1,143 mt) to remain at the beginning of 1990, and 59% more SSB (721 mt).

DISCUSSION

Results of this assessment are similar to those for Southern New England; they indicate that the Georges Bank yellowtail flounder stock has undergone significant increases in fishing mortality; levels are now very high while SSB is very low.

Fishing mortality in 1987 was 0.925 based on reported landings (2,743 mt); F88 would increase to 1.2-1.3, corresponding to the annual projection based on reported 1988 landings (1,866 mt). Recruitment has been poor since the 1984 year class became vulnerable to fishing in 1986. This year class was dramatically recruited to the fishery, but the estimated number of age 1's remained 35% lower than the 1968-1983 average.

Estimated recruitment to the stock in 1987 was 68% lower than in 1986, 95% below the 1969-1986 average, and was the absolute lowest value in the VPA time series. Considering the trend of declining year class strength reflected by recent NEFC bottom trawl surveys, results of the VPA, and marked increases in fishing mortality, Projection C would appear the most appropriate of the three presented. A very significant reduction in the level of fishing mortality is critical to recovery of the Georges Bank stock.

OTHER YELLOWTAIL FISHERIES IN THE NORTHWEST ATLANTIC

CAPE COD

Landings on the Cape Cod grounds have averaged 2,200 mt annually since 1960 (Table 1). There was an isolated peak in 1963 (3,600 mt). And, a trend of high landings from 1976 through 1982, averaging 3,800 mt and peaking in 1980 at 5,100 mt. Landings have since declined to average 1,000 mt since 1984, but increased to 1,200 mt in 1987.

The commercial CPUE index also peaked in 1963 at 4.6 thousand mt/day fished, was moderately high during the early 1960's and 1970's, and then declined to average 1.8 thousand mt/day fished from 1973 through 1983. There has since been a sharp decline to average only 0.75 thousand mt/day fished; the 1987 value is 0.7 thousand mt/day fished.

The NEFC offshore autumn bottom trawl survey time series (1963-1986) averages for abundance and biomass indices are 3.97 fish/tow and 1.21 kg/tow. Both indices peaked in 1963 and 1972, were moderately high during 1976-1982 (peaking in 1977 and 1980). Both indices declined to time series low points in 1983 of 0.15 fish/tow and 0.05/tow kg, respectively. There was a trend of increase during 1984-1986, with improved recruitment. However, both indices have since declined sharply in 1987, to 0.25 fish/tow (-93% from 1986) and 0.08 kg/tow (-87% from 1986).

Spring survey data do not corroborate the timing of all peaks in the autumn, neither in abundance nor biomass. However, it does reinforce the improved abundance and biomass observed in the early 1980's. The abundance and biomass indices for spring 1987 were 7.66 fish/tow and 4.32 kg/tow, the highest values observed in the 1968-1987 time series; 89% in abundance was contributed by the 1985 year class. The 1988 total indices decreased 71% in number and 91% in weight.

MIDDLE ATLANTIC

Trends in the Mid-Atlantic have been similar to those for Southern New England. Annual commercial landings from the Mid-Atlantic averaged 2,300 mt over the recorded period (1964-1987, Table 1). They were most substantial from 1964 through 1974, averaging 4,100 mt annually. Landings have since declined sharply to average 500 mt from 1975-1981, and then increased in the early 1980's with improved recruitment to 1,700 mt annually (1982-1984). Subsequent landings have again decreased to average 260 mt during 1985-1987; 1987 landings (340 mt) are -85% below the time series average.

As for Southern New England, survey abundance indices for the Mid-Atlantic declined during the mid-to-late 1970's, increased during the early 1980's with improved recruitment, and declined to time series (1963-1986) lows in each category by 1987. The 1988 spring survey reflects minimal increases in both abundance and biomass.

GULF OF MAINE

Landings for the Gulf of Maine yellowtail fishery have averaged 240 mt annually since 1969; 1987 landings were 200 mt (Table 1). Landings averaged 130 mt annually during 1969-1975. More significant landings occurred during the late 1970's and early 1980's, averaging 360 mt during 1976-1983. Annual reported landings since 1984 have approximated 200 mt.

GRAND BANKS OF NEWFOUNDLAND

In April of 1985, New England based otter trawlers began a directed fishery for yellowtail, American plaice (*Hippoglossoides plattessoides*), and witch flounder (*Glyptocephalus cynoglossus*) on the Grand Banks of Newfoundland (outside the 200 mile limit) in an area known as "Tail of the Bank". This area lies within Northwest Atlantic Fisheries Organization (NAFO) Divisions 3N and 30. This time and fuel expensive option (usually a four day steam each way) was exercised in response to the low levels being landed in traditionally fished U.S. waters. Total yellowtail landings from traditionally fished waters in 1985 were 72% below the 1960-1984 annual average.

Yellowtail landings from the Grand Banks in 1985 were 3,800 mt (34% of the U.S. total); landings declined to 2,600 mt in 1986 (25% of the U.S. total), and again to 1,500 mt in 1987 (21% of the U.S. total). Preliminary 1988 U.S. landings increased to 5,000 mt (17% of the U.S. total).

GENERAL DISCUSSION

Virtual Population Analysis is a powerful tool that is widely used in the assessment of exploited marine fisheries. It provides estimates of stock size and instantaneous fishing mortality. But like many estimation procedures, it may be adversely affected by various errors relative to data input. Pope (1972) looked at errors resulting from incorrect estimation of fishing mortality during the final age of exploitation (F_t), and from sampling errors of catch data. His estimates of the size of such errors suggest a convergence of the fluctuations in resulting stock size estimates to fairly small values; with the high F_t levels estimated for both yellowtail flounder stocks, this convergence should occur rapidly (Ulltang 1977).

Ulltang (1977) studied various other sources of error in virtual population analysis, including natural mortality, seasonal variations in natural and fishing mortality, and stock migration. Errors in VPA caused by uneven distribution of natural or fishing mortality were generally shown to be small or negligible. Ulltang concluded that estimation of stock size would correspond to the over or under estimation of natural mortality. Estimates of relative year to year changes in stock size, however, should be approximately correct; Agger et al. (1971) reported similar findings. The yellowtail flounder natural mortality estimate used in this document was not arbitrary; it was based on analyses of stomach contents, and marking experiments (Lux 1969b). Stock migration was not thought to be a critical factor in the analyses presented. Seasonal movements of yellowtail flounder have been reported (Lux 1963), however no continuous annual age specific migrations at a constant rate, as described by Ulltang, have been documented.

Sims (1982) investigated the relative error in VPA stock size estimates when catches are unevenly distributed throughout the year. He found the effects to not be severe unless the natural mortality is large and/or the fishery is heavily exploited. However, if the fishery is seasonal with heavy exploitation at one end of the year or the other, and if natural mortality is high and/or the fishery is heavily exploited, then the relative error in stock size can be unacceptably large. Generally, landings in the U.S. yellowtail flounder fishery are quite evenly distributed throughout the year; however, catches of unmarketable sized fish may increase significantly during the fourth calendar quarter of a given year if a year class is strongly recruited to the fishery. Sims defines a measure of intra-year distribution of catches called the balance. A relationship is derived between the relative error in VPA stock size estimates, the balance, natural and fishing mortality rates. Such measures may be valuable for interpreting the results of yellowtail flounder VPA's.

Construction of catch-at-age matrices used in this document required the development of methods which made use of existing data and accessible information. U.S. landings, U.S. discard, U.S. industrial catch, and catches by foreign nations were estimated.

Fishery discards are among the most difficult population data to monitor and/or estimate. A systematic method was developed, presenting an alternative to estimates based solely on the proration of reported discard levels obtained from a sampling of landed commercial vessels, as used in previous assessments.

Between 1969 and 1985 commercial interview coverage for yellowtail flounder landings ranged from 1 interview per 14 metric tons landed down to 1 per 1415 metric tons. One sample per 200 metric tons is a generally used rough rule of thumb for representative coverage. Commercial sea sampling data for yellowtail flounder was summarized and found unsuitable to develop a catch-at-age matrix for the given time series with respect to: 1) temporal and spatial coverage of both fisheries, 2) consistency in sampling methodology, and 3) useful presentation of data.

The strengths of the method for estimating commercial discard used in this study lie in its comprehensive use of: 1) regulated mesh sizes, and 2) both commercial and NEFC bottom trawl survey data. It is less dependent on commercial interviews to fully represent discard levels in all relevant areas; this is an advantage considering results of the aforementioned evaluation of discard interviews. Discard estimates made using this method may be lower than actual historic levels; use of NEFC bottom trawl survey data to estimate population structure of unmarketable flatfish is less than ideal, because roller gear is routinely used. The ability of this survey data to accurately reflect relative numbers of small (unmarketable) yellowtail is likely to be somewhat density dependent.

Estimation of discards with the selection curves from a smaller than regulated sized codend mesh would yield results which reflect use of smaller sized mesh. This measure may be particularly useful for the final three years of the Southern New England time series. During this period, management was under the Interim (Atlantic Demersal Finfish) Plan which required no minimum legal mesh size westward of 70^{o}W longitude. Statistical area 526, where typically 50-70% of Southern New England yellowtail are caught, was included in the Large Mesh Area. However, contributions from statistical areas 537-539 remained substantial. The mesh sizes used in this analysis reflect the mode reported as having been used by commercial vessels landing yellowtail caught in these unregulated areas; actual mesh sizes used in this fishery were probably smaller.

An earlier attempt at virtual population analysis of the Georges Bank stock (Parrack 1976 MS) used a catch-at-age matrix covering the 1963-1975 period. Parrack's estimation techniques were quite different from those used in the present analysis, particularly for U.S. discard and foreign catch-at-age, thus there are some relatively large differences between the two analyses. However, trends reflected during overlapping years were similar.

Yield and spawning stock biomass per recruit analyses for the Southern New England stock were performed by Clark et al. (1985) to evaluate the implications of recent fishing patterns and fishing mortality levels. Clark focused on the Southern New England stock. Growth, mortality, and maturation estimates used were the same as in Gabriel et al. (1984). Results demonstrated considerable potential benefits associated with reductions in fishing mortality and/or increases in the time of first capture. Clark concluded that observed low abundance in all areas and extremely poor recruitment prospects indicate that continued declines can be expected in the immediate future.

The catch and stock size projections for Southern New England and Georges Bank stocks presented in this document cover a range of possible fishing mortality scenarios. Recruitment levels in 1987 were estimated through regression of NEFC survey numbers per tow at age 1 vs. VPA estimates of recruitment at age 1. Catch in 1988 is based on preliminary 1988 landings reports (discard not included). The tabulated fishing mortality for 1988 was estimated using NEFC's catch and stock size prediction program. Stock size estimates for the final years of any VPA time series are uncertain before convergence takes place. The high F's indicated for both these yellowtail flounder fisheries in 1986 would suggest rapid convergence. However, uncertainty surrounding any type of forward projection should be anticipated.

Results of the analyses presented in this document indicate that fishing mortality increased to very high levels during the early 1980's, and that stock biomass is now very low. These findings are corroborated by trends in both commercial and research survey abundance indices, and by the assessments of previous scientists. It is recognized that the management of yellowtail flounder stocks would be enhanced through the use of more absolute measures of stock size and fishing mortality, not simply descriptive stock assessments. However, dissimilarity in the conduct of different components of the yellowtail flounder fisheries, and data shortages have delayed making a viable attempt at this goal. This research makes that attempt; its results reconstruct the history of Southern New England and Georges Bank yellowtail flounder stocks during the last two decades in absolute terms.

SUMMARY AND CONCLUSIONS

Commercial landings of yellowtail flounder (5Z E & W of 69°W plus SA6, Table 1) increased from 15,600 metric tons (mt) in 1981 to 33,100 mt in 1983. Landings have since declined to only 7,600 mt in 1987, 29% less than in 1986, and the lowest annual catch since 1956. Of the 1987 total, Georges Bank landings comprised 37%, Southern New England landings 21%, Grand Banks landings 20%, Cape Cod landings 16%, Gulf of Maine landings 3%, and Mid-Atlantic landings 2%. With the exception of the Gulf of Maine and the Mid-Atlantic, landings in all areas declined between 1986 and 1987.

Commercial catch per unit effort (CPUE, Table 3) for Southern New England, Georges Bank and Cape Cod areas, and research vessel survey indices for Southern New England and Georges Bank (Tables 4 & 5) indicate that abundance levels have declined steadily since the 1979-1981 year classes were recruited to the fishery. The 1984 year class appeared stronger than those immediately preceeding, based on spring 1986 survey data and its dramatic recruitment to the fishery in the fall of 1986. It, however, was not a strong one and did not sustain elevated landings beyond 1987.

Virtual population analysis of commercial catch-at-age data covering the 1970-1986 period for Southern New England (Table 14) indicates that fishing mortality ranged from 0.604 in 1971 to 1.922 in 1984. During the same period spawning stock biomass (SSB) decreased 92%, from 38,198 mt in 1970 to a time series low of 3,200 mt in 1985; 1985 total biomass (4,793 mt) was also the lowest in the time series. Similar trends in fishing mortality and stock biomass are reflected by estimates based on survey data.

Yield per recruit analysis for Southern New England (Table 16, Figure 20) indicate that F in 1986 far exceeded both $F_{0.1}$ (0.210) and F_{max} (0.545). F in 1986 (1.48) was approximately 7 times larger than $F_{0.1}$, and nearly 3 times larger than F_{max}. Relative to F_{max}, the 1986 F would generate approximately 35% less stock biomass per recruit and 60% less spawning stock biomass per recruit under equilibrium conditions.

Catch and stock size projections for Southern New England (Tables 18 & 19) were made using two different estimation methods for predicting 1988-1990 annual recruitment. Each projection indicated little improvement in SB and SSB at current F levels. Reduction of F to F_{max} could result in increased stock biomass, but SSB would still be well below the long-term average through 1990.

Virtual population analysis of the Georges Bank stock covering the 1969-1986 period shows that fishing mortality increased nearly 5 fold, from 0.539 in 1971 to 1.997 in 1984 (Table 15). During the same period SSB decreased 94%, from 41,887 mt in 1969 to 2,467 in 1985; 1985 total biomass (3,489 mt) was also the lowest in the time series. Trends in fishing mortality and biomass indices produced from NEFC groundfish survey data support VPA results.

Yield per recruit analysis for Georges Bank (Table 17, Figure 21) indicates that F in 1986 (0.83) was nearly 4 times greater than $F_{0.1}$ (0.211), and over 42% higher than F_{max} 0.584). Relative to F_{max}, the 1986 F generates approximately 14% less stock biomass per recruit and 25% less spawning stock biomass per recruit under equilibrium conditions.

Catch and stock size projections for Georges Bank (Tables 20-22) were made using three different estimation methods for predicting 1988-1990 annual recruitment. Each projection shows continued reductions in SB and SSB at current high F levels. Reduction of F to F_{max} could result in increased stock biomass, but the resultant stock size would still be well below the long-term average through 1990.

In conclusion, this 1988 assessment of yellowtail flounder stocks in the Northwest Atlantic does not paint an optimistic picture. Trends in U.S. fisheries off the northeast coast, as reflected by commercial and survey indices of abundance, show declines which appear largely related to over exploitation. Virtual population analyses of Southern New England and Georges Bank stocks clearly indicate that fishing mortality levels have increased dramatically during their relative time series. While, stock biomass and spawning stock biomass levels have, in turn, been decreased severely. Recruitment estimates provided by VPA results and NEFC bottom trawl survey indices do not look favorable. Yield per recruit analyses indicate that recent F levels will not lead to increases in

SB and SSB. Catch and stock size projections indicate continued reductions in SB and SSB at current high F levels. Given the current condition of the resource, improved recruitment and significant reductions in fishing mortality are critical to the recovery of these stocks.

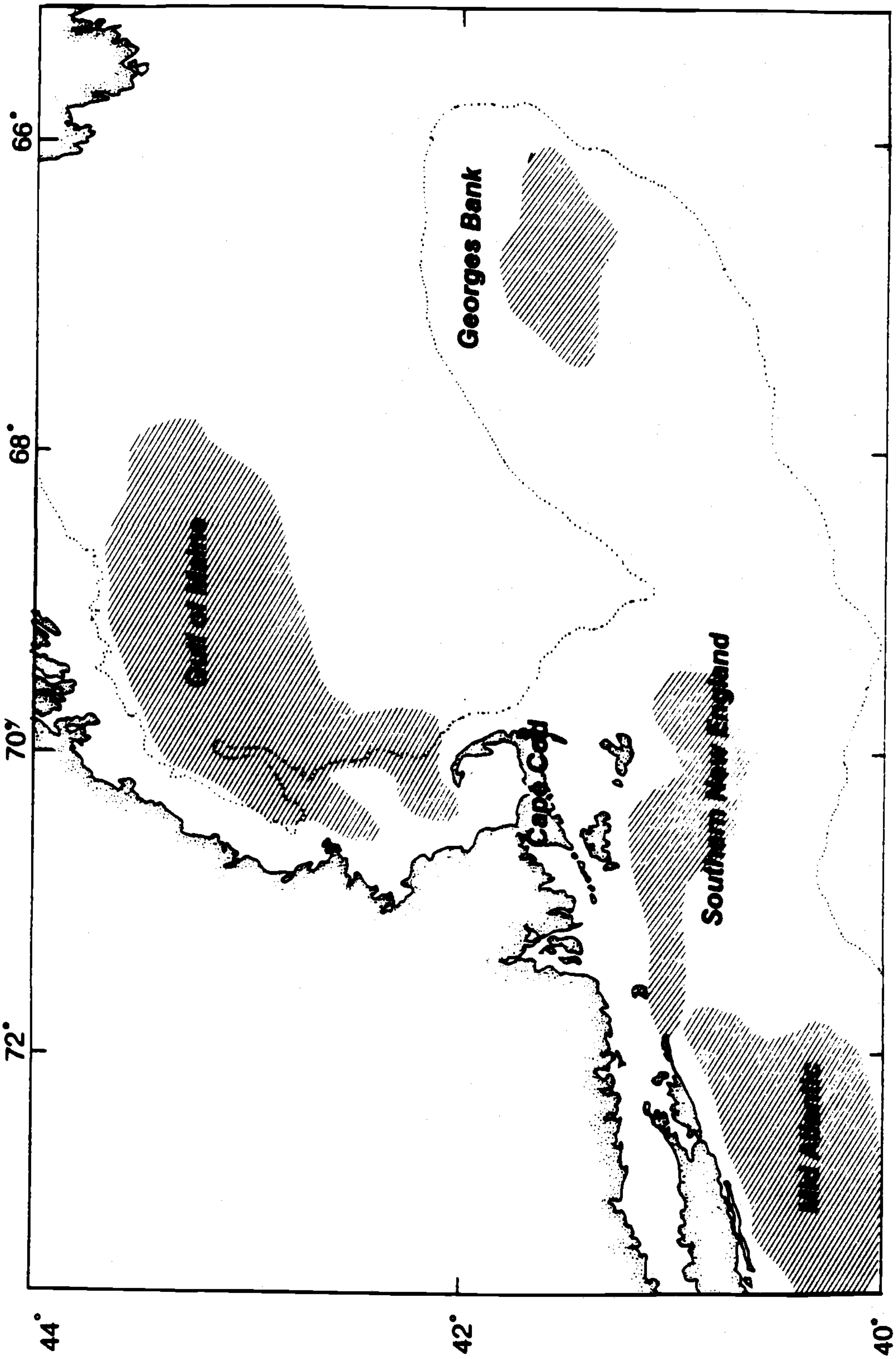


Figure 1. United States yellowtail flounder fishing areas off New England and in the Middle Atlantic.

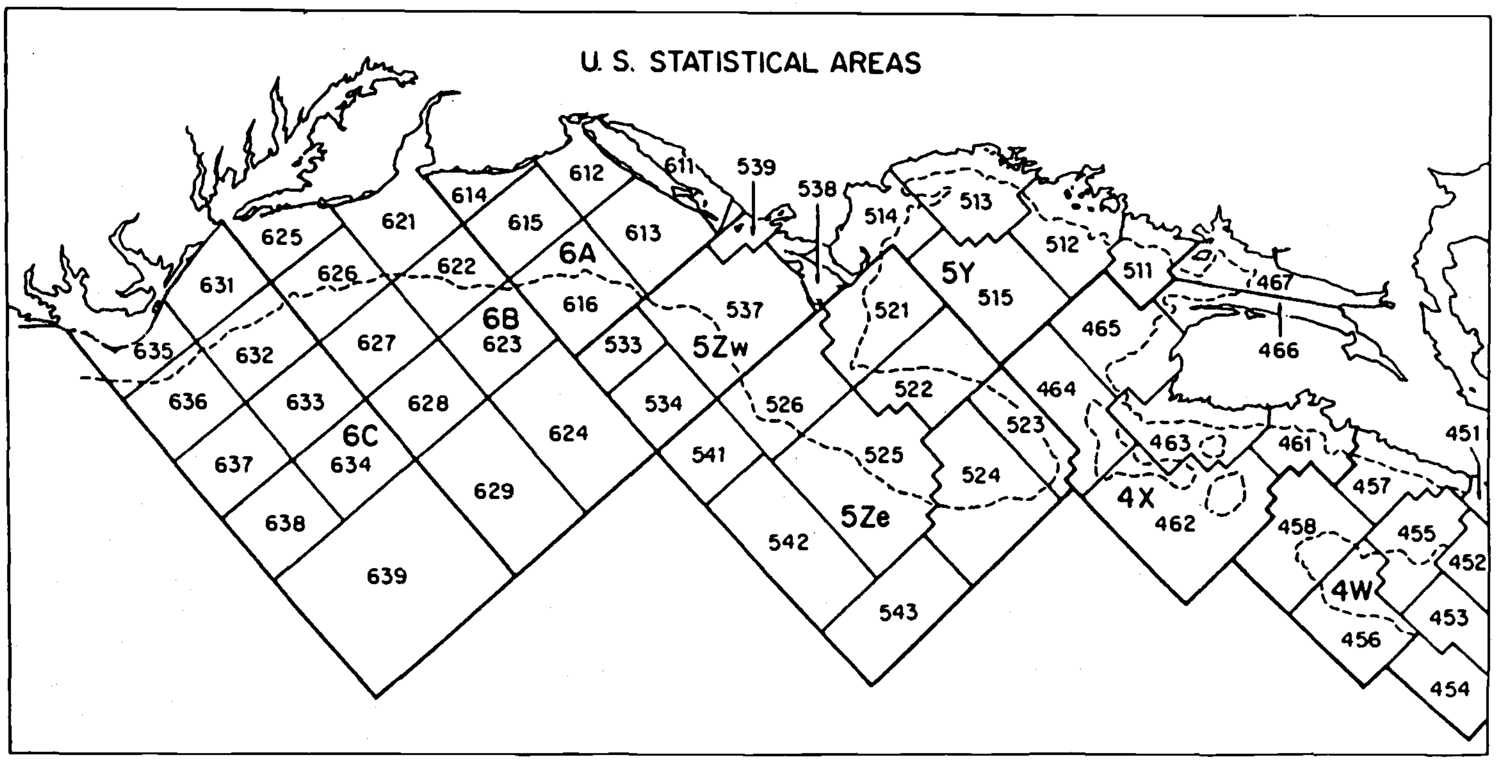


Figure 2. Northwest Atlantic Fisheries Organization divisions and sub divisions (bold lettering), and U. S. statistical areas. Yellowtail fishing grounds defined by statistical areas are as follows: Southern New England, 526-539; Georges Bank, 522-525; Cape Cod 514 and 521; Mid-Atlantic, 611 plus; Gulf of Maine, 511-513 and 515.

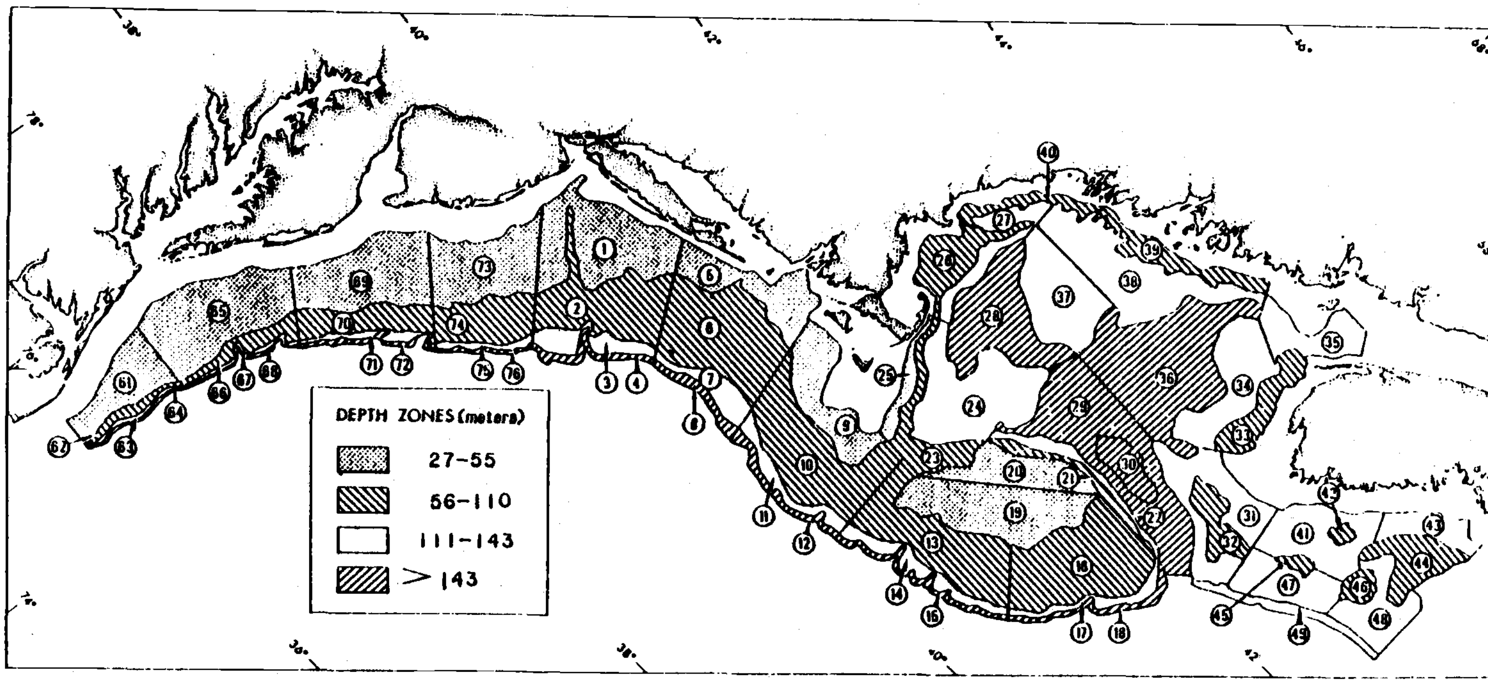


Figure 3. Strata used in NEFC offshore (>27m) spring, summer, and autumn bottom trawl surveys.

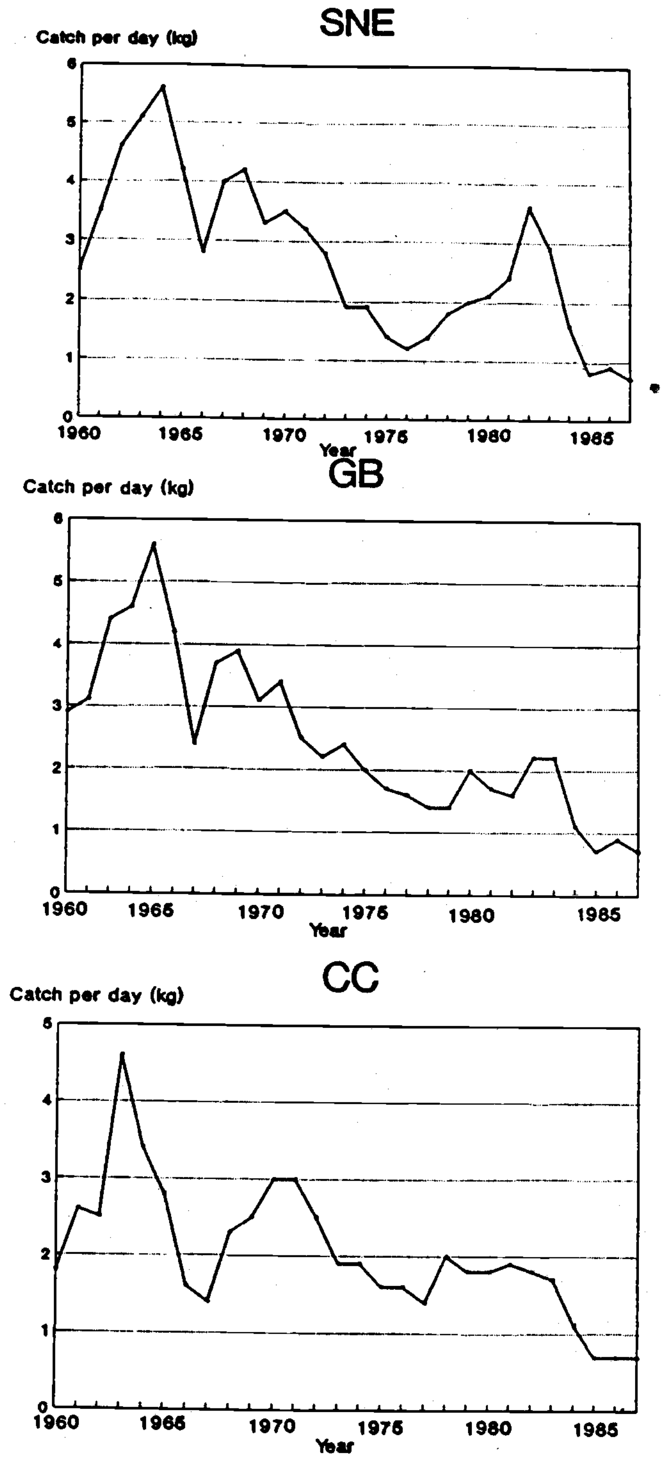
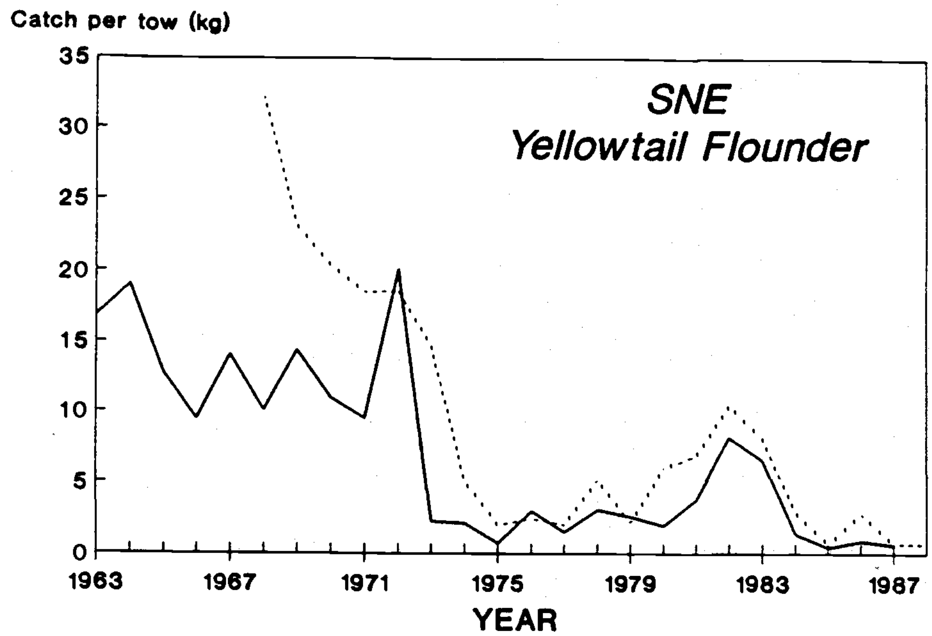


Figure 4 . Commercial abundance indices (metric tons per standard day fished) for Southern New England, Georges Bank, and Cape Cod yellowtail flounder, 1960-1987.



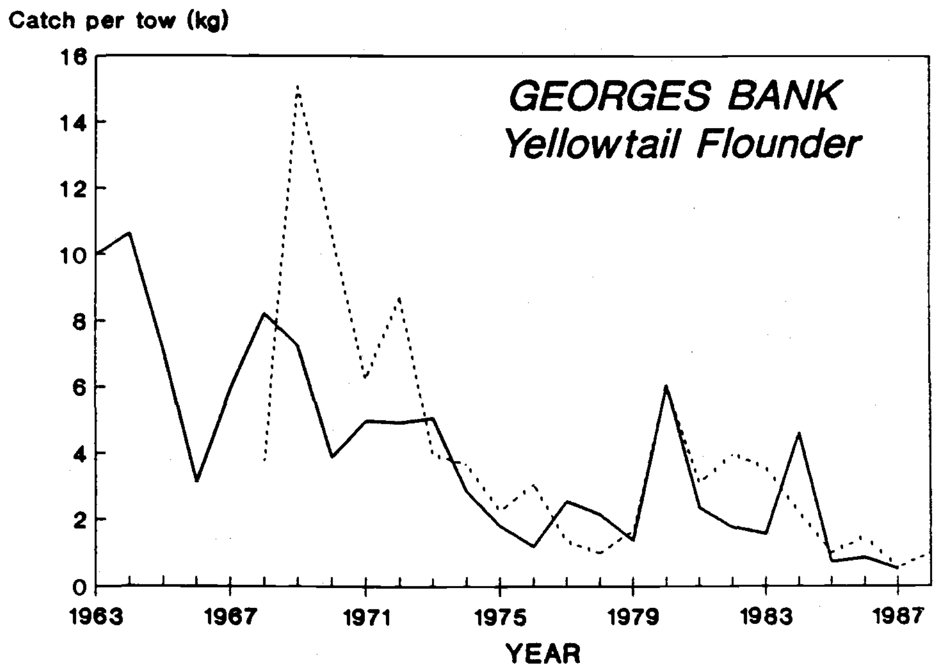


Figure 5. Stratified mean catch per tow (kg) of Southern New England (strata 5, 6, 9, & 10) and Georges Bank (strata 13-21) yellowtail flounder from NEFC offshore spring (----) and autumn (——) surveys, 1963-1987.

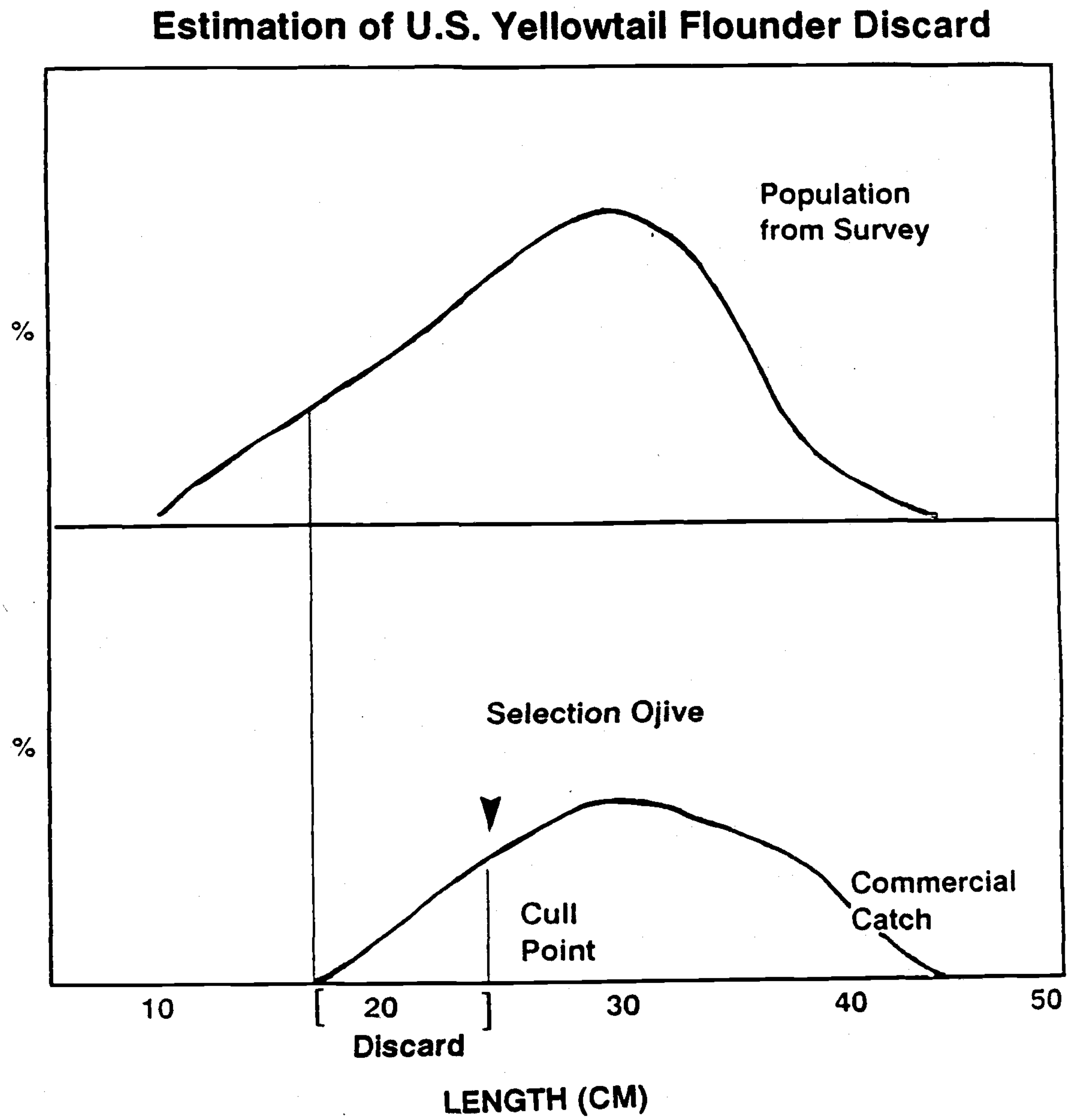


Figure 6. Schematic representation of discard estimation technique for Southern New England and Georges Bank yellowtail flounder catch-at-age matrices.

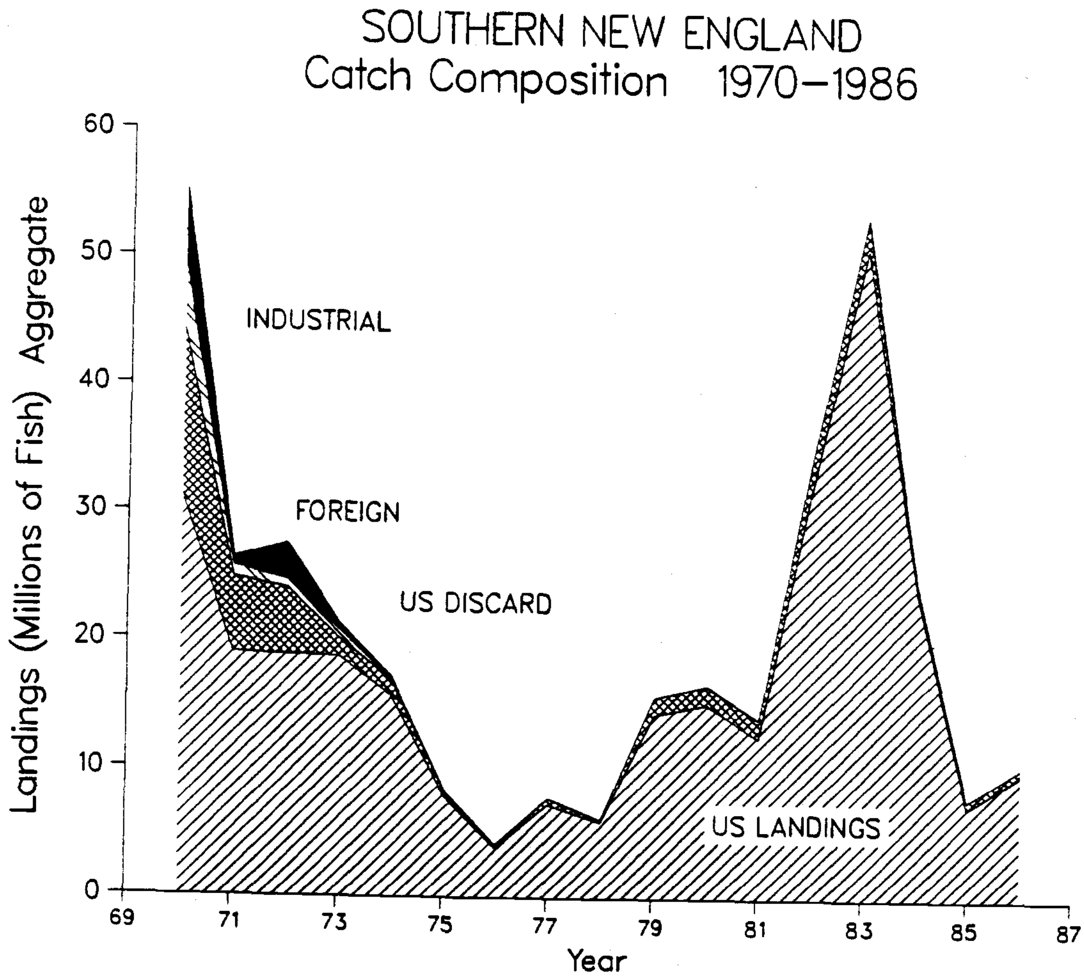


Figure 7. Structure of total catch composition (millions of fish, cumulative) from Southern New England yellowtail flounder fishery (Statistical areas 526, 537-539), 1970-1986.

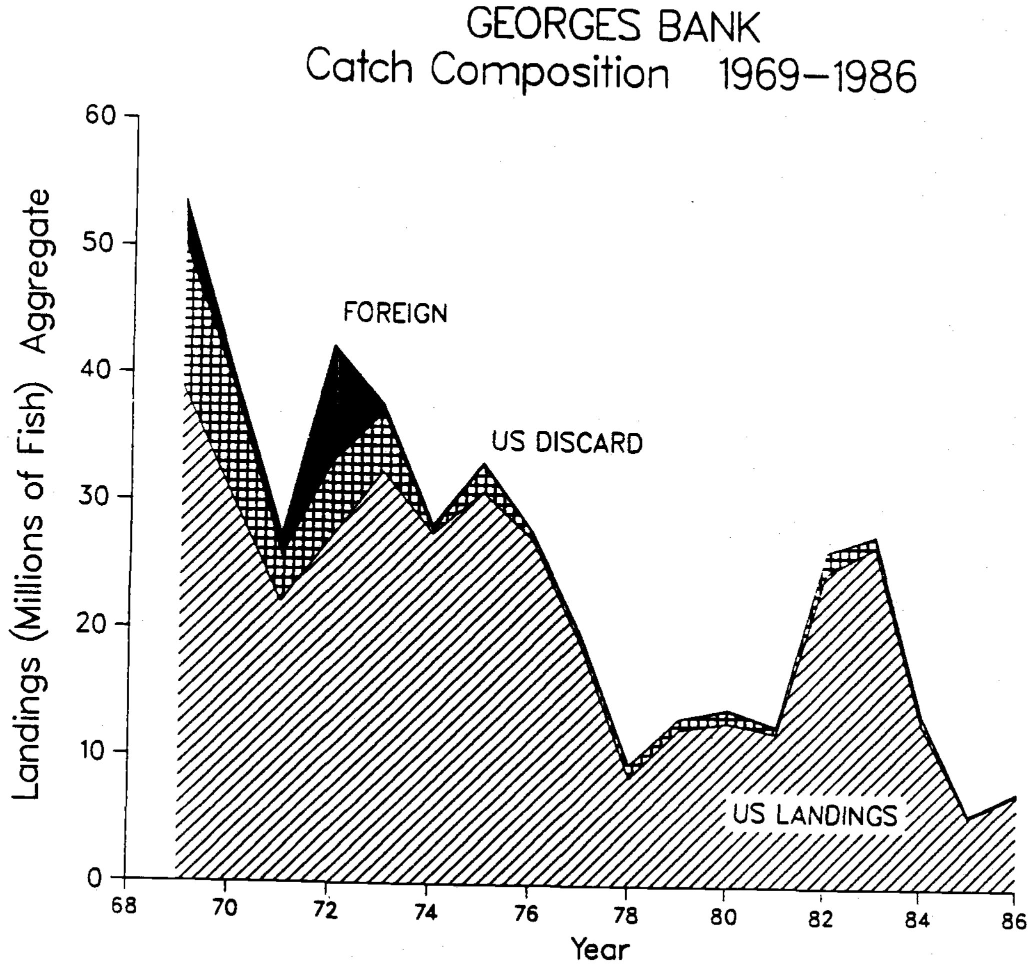
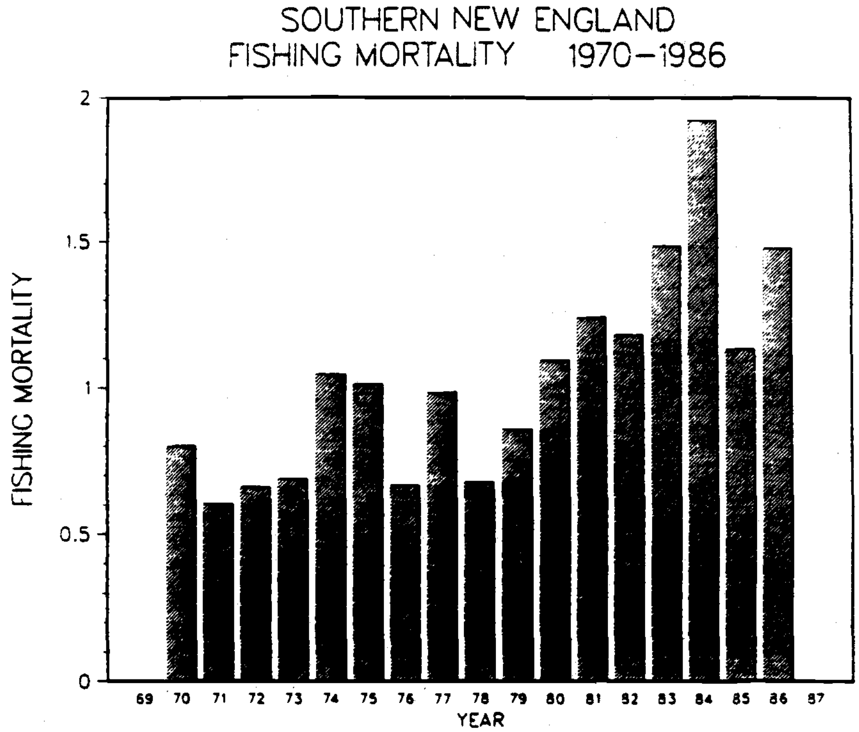


Figure 8 . Structure of total catch composition (cumulative, in numbers) from Georges Bank yellowtail flounder fishery (statistical areas 522-525), 1969-1986.



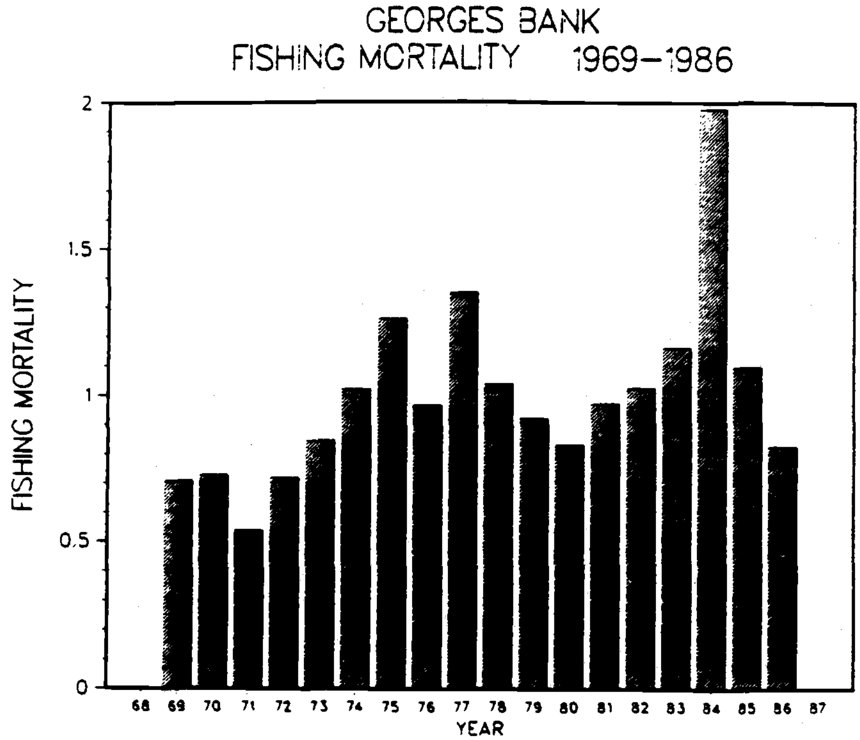


Figure 9. Fishing mortality estimates (VPA) for Southern New England (Statistical areas 526-539) and Georges Bank (Statistical areas 522-525) yellowtail flounder fisheries.

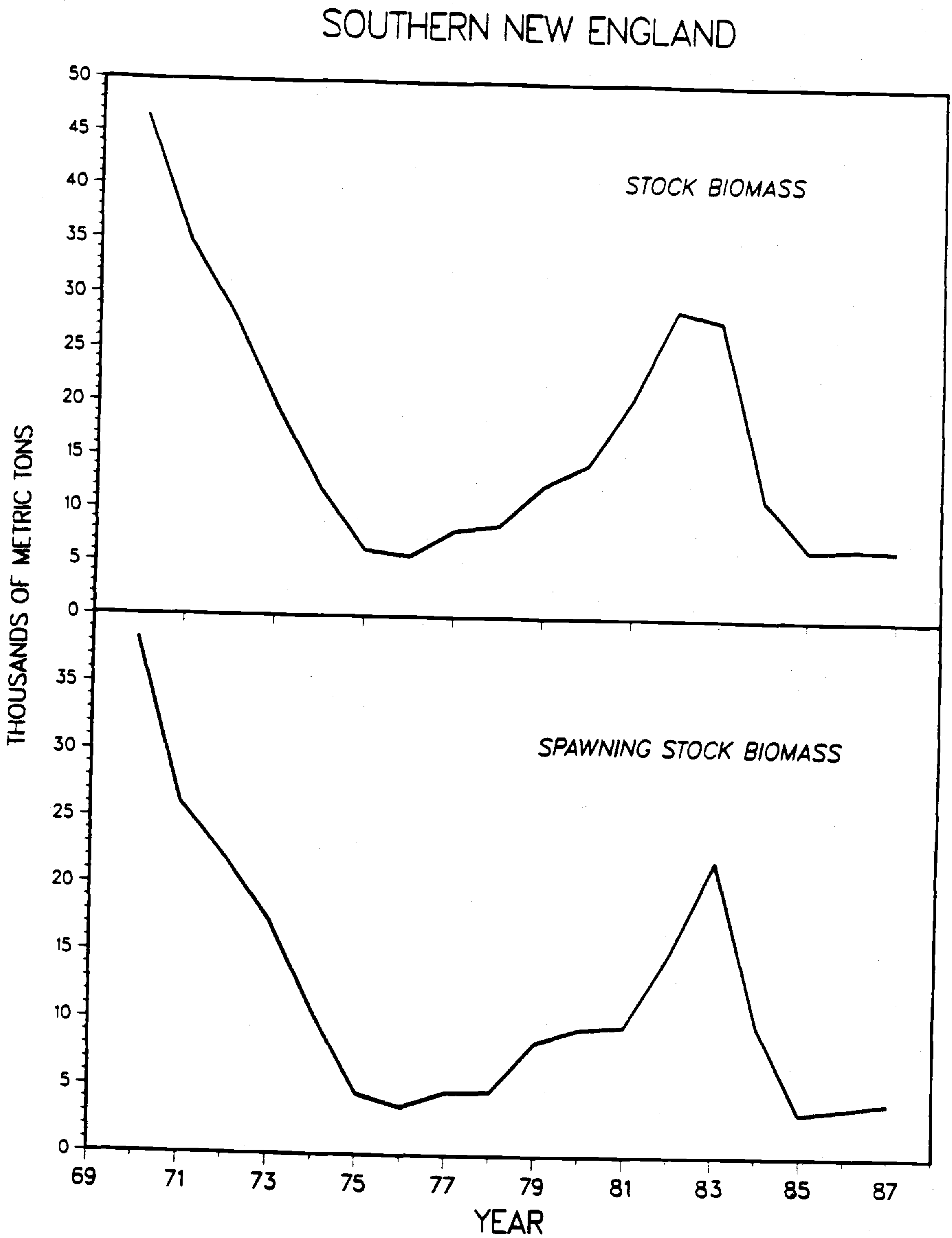


Figure 10. Stock biomass (ages 1-8+) and spawning stock biomass (Morse 1979 maturity ogive) for So. New England yellowtail flounder in thousands of metric tons as estimated through virtual population analysis (1969-1986).

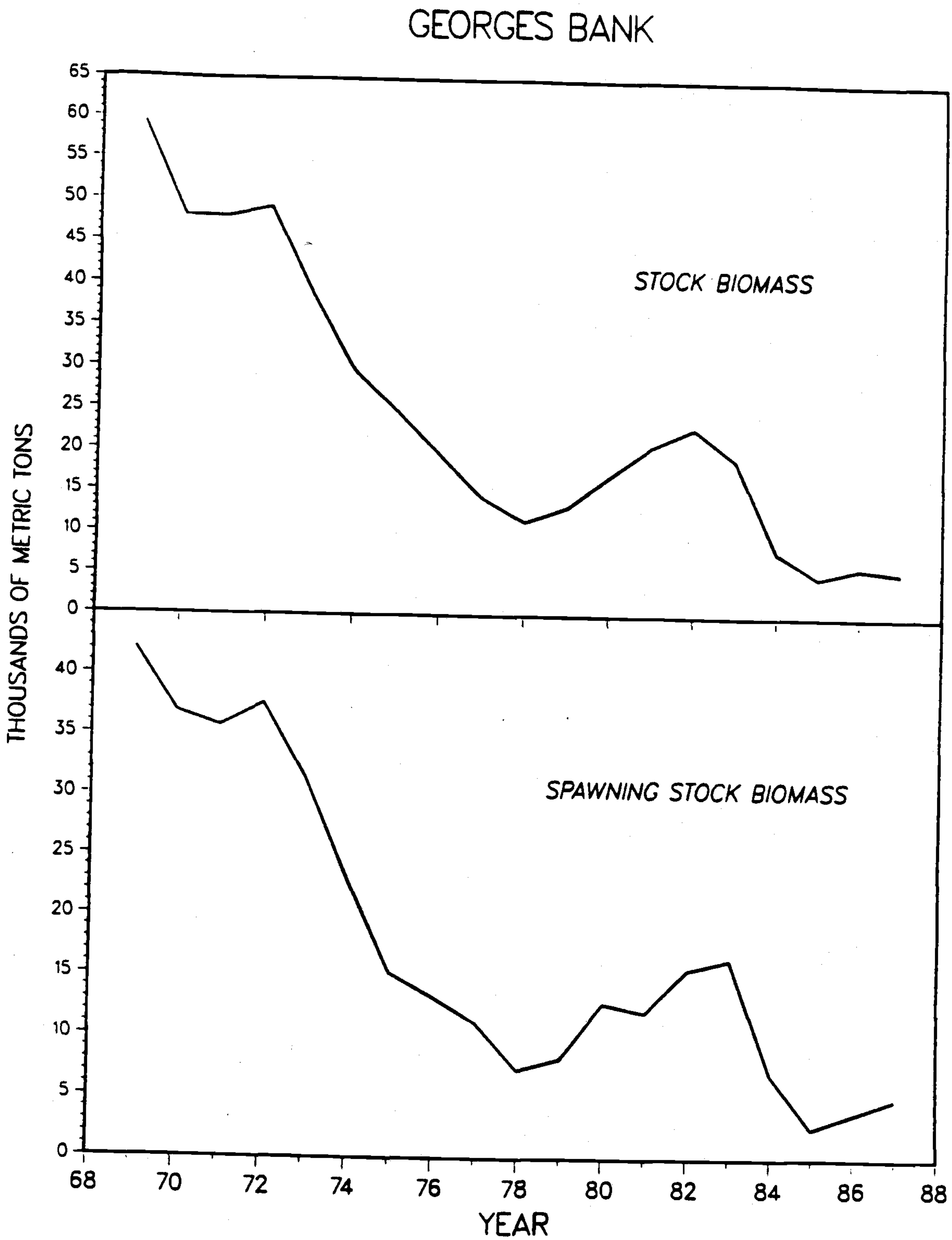


Figure 11. Stock biomass (ages 1-8+) and spawning stock biomass (Morse, 1979 maturity ojive for Georges Bank yellowtail flounder in thousands of metric tons as estimated through virtual population analysis (1969-1986).

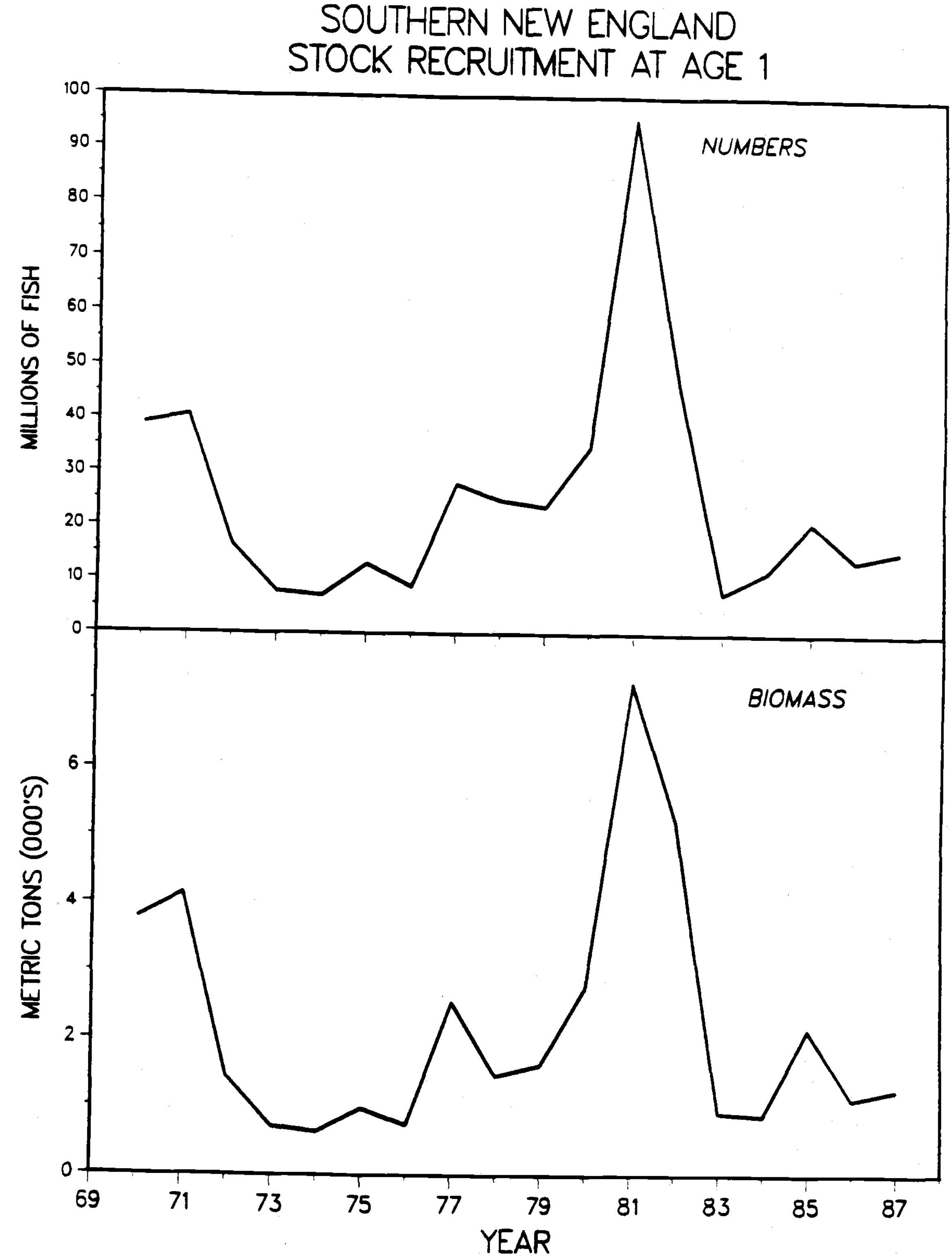


Figure 12. VPA estimated stock recruitment at age 1 for Southern New England yellowtail flounder (1970-1987, statistical areas 526-539) in millions of fish and thousands of metric tons.

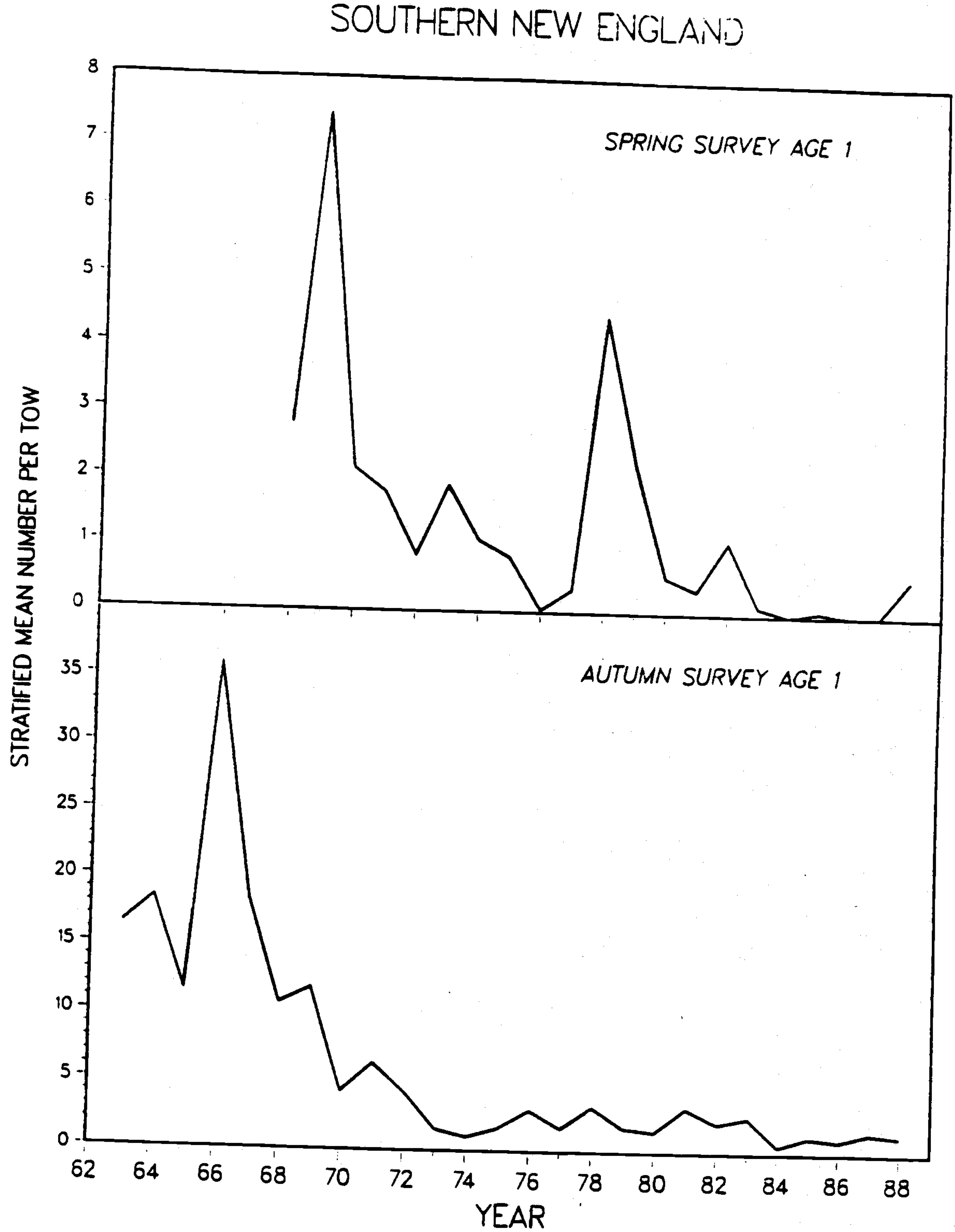


Figure 13. Stratified mean number per tow at age 1 for Southern New England yellowtail flounder in NEFC offshore spring and autumn bottom trawl surveys, 1963-1988.

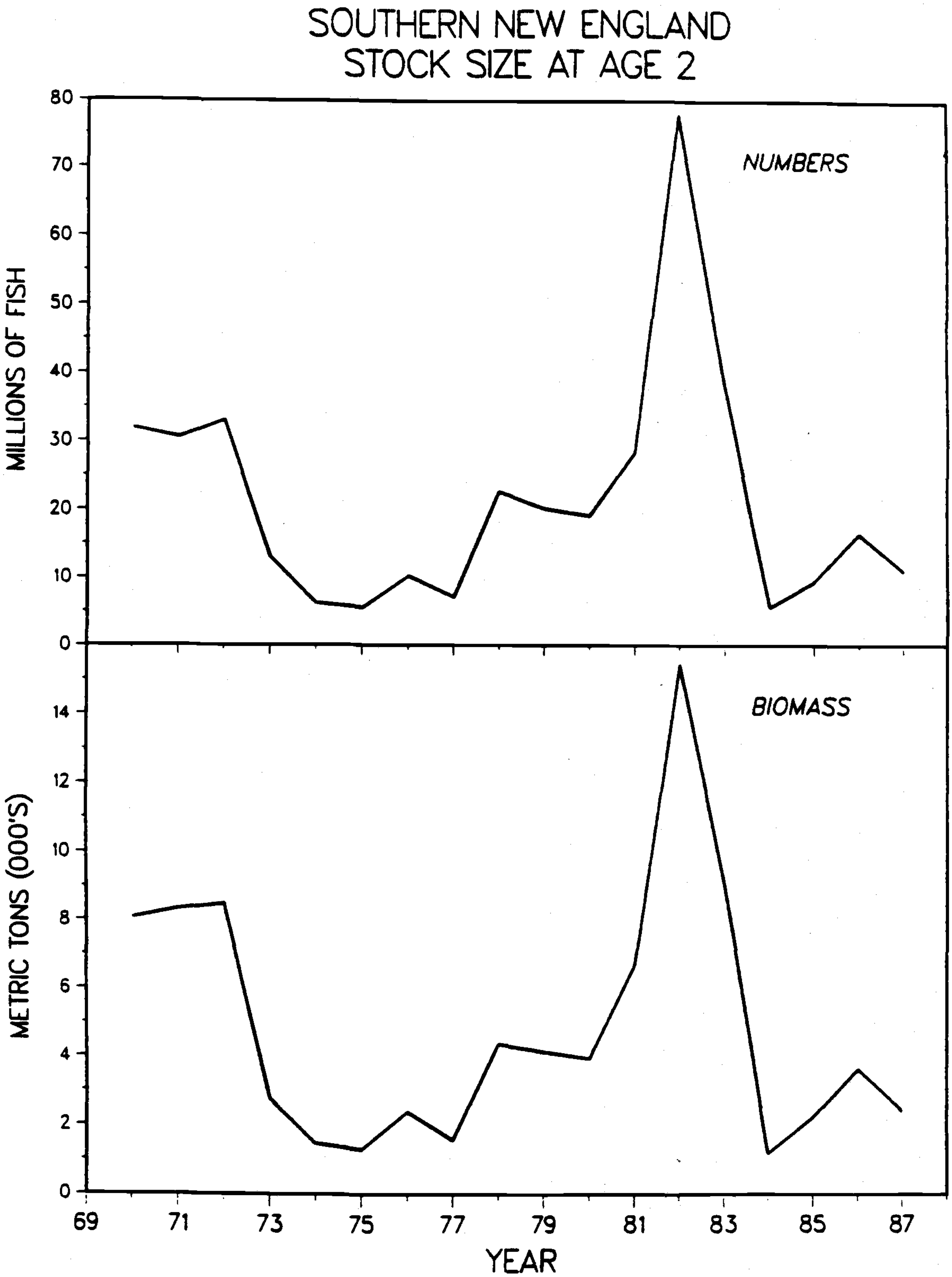


Figure 14. VPA estimated stock size at age 2 for Southern New England yellowtail flounder (1970-1987, statistical areas 526-539) in millions of fish and thousands of metric tons.

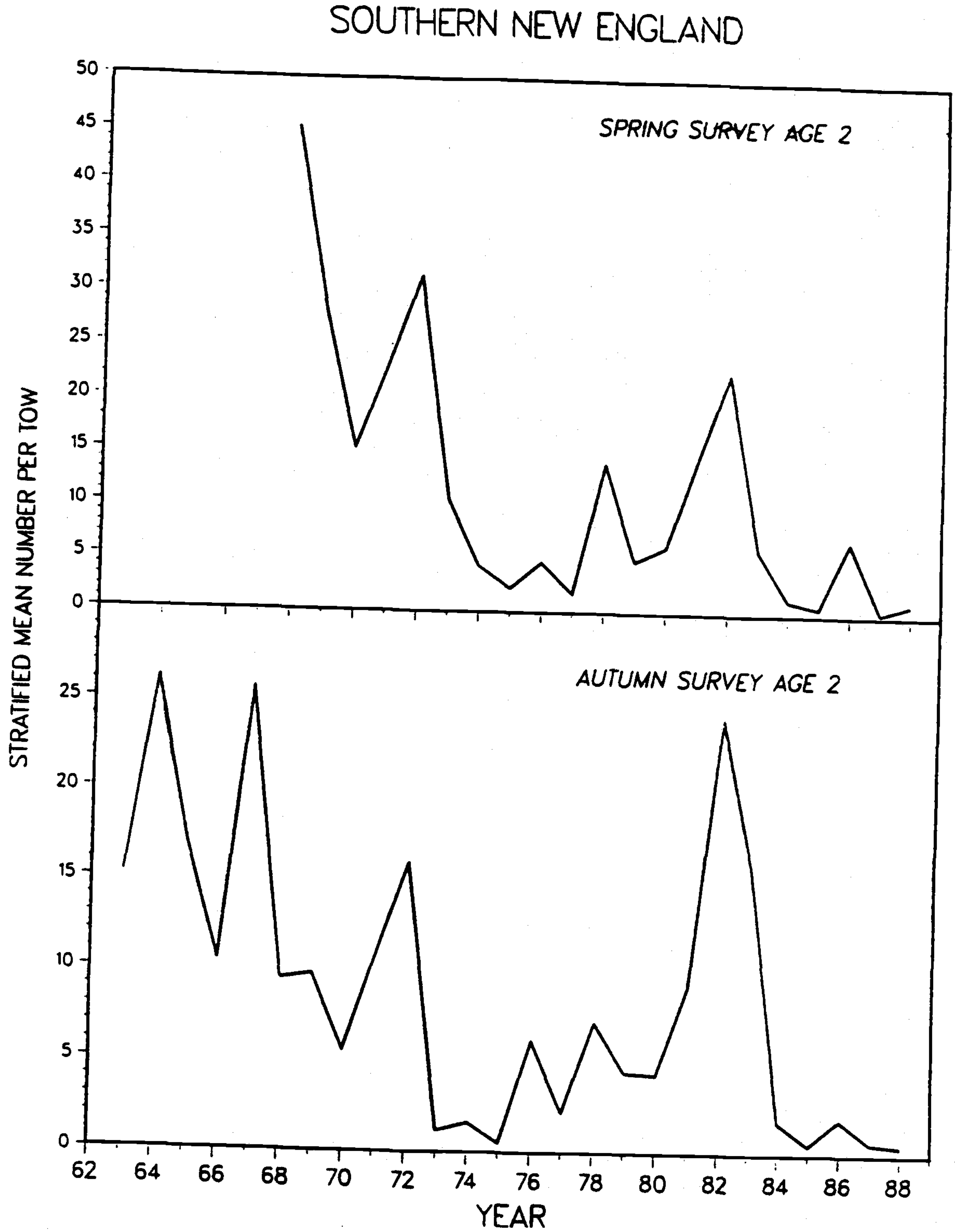


Figure 15. Stratified mean number per tow at age 2 for Southern New England yellowtail flounder in NEFC offshore spring and autumn bottom trawl surveys, (1963-1988).

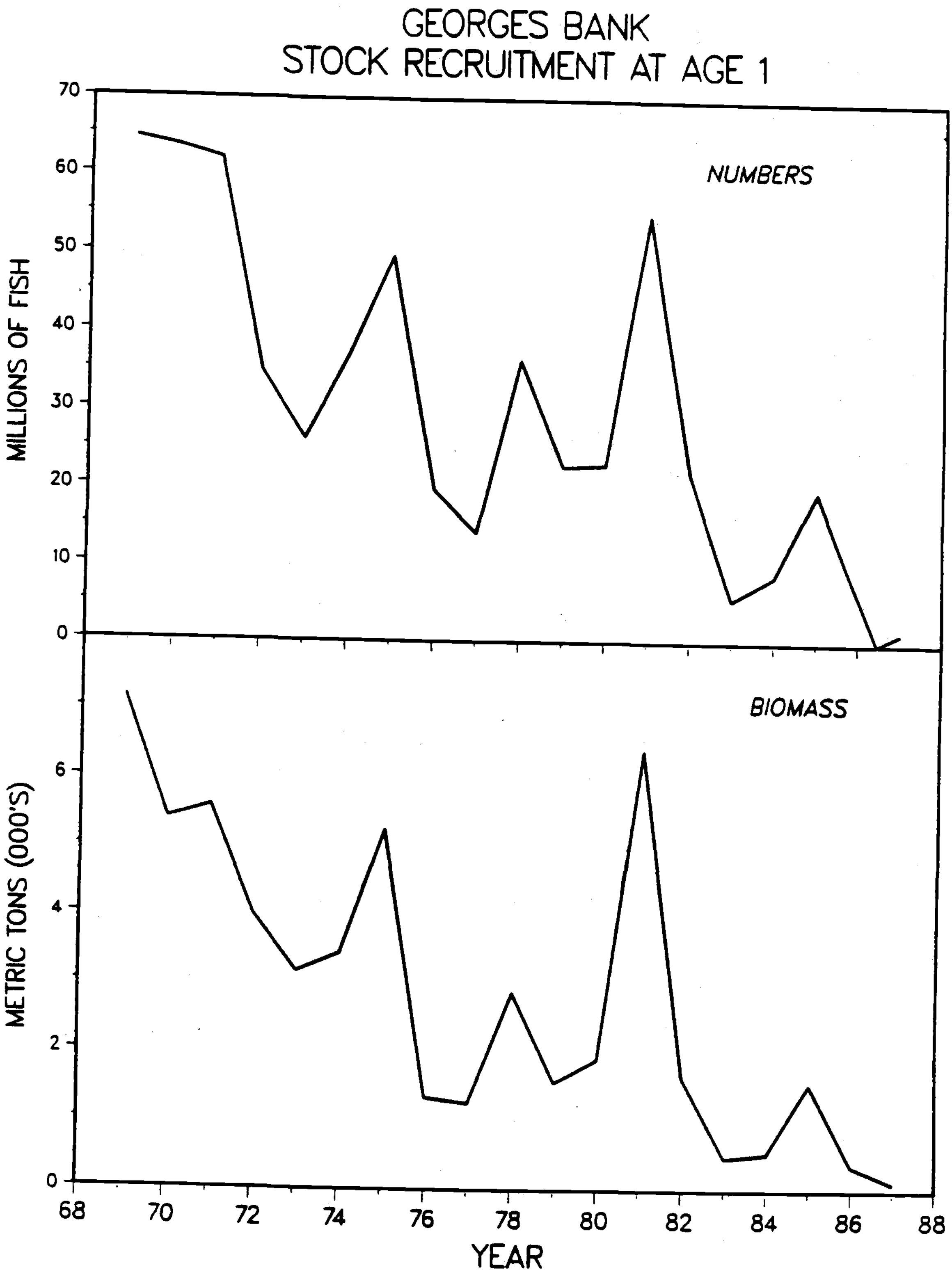


Figure 16. VPA estimated stock recruitment at age 1 for Georges Bank yellowtail flounder (1969-1987, statistical areas 522-525) in millions of fish and thousands of metric tons.

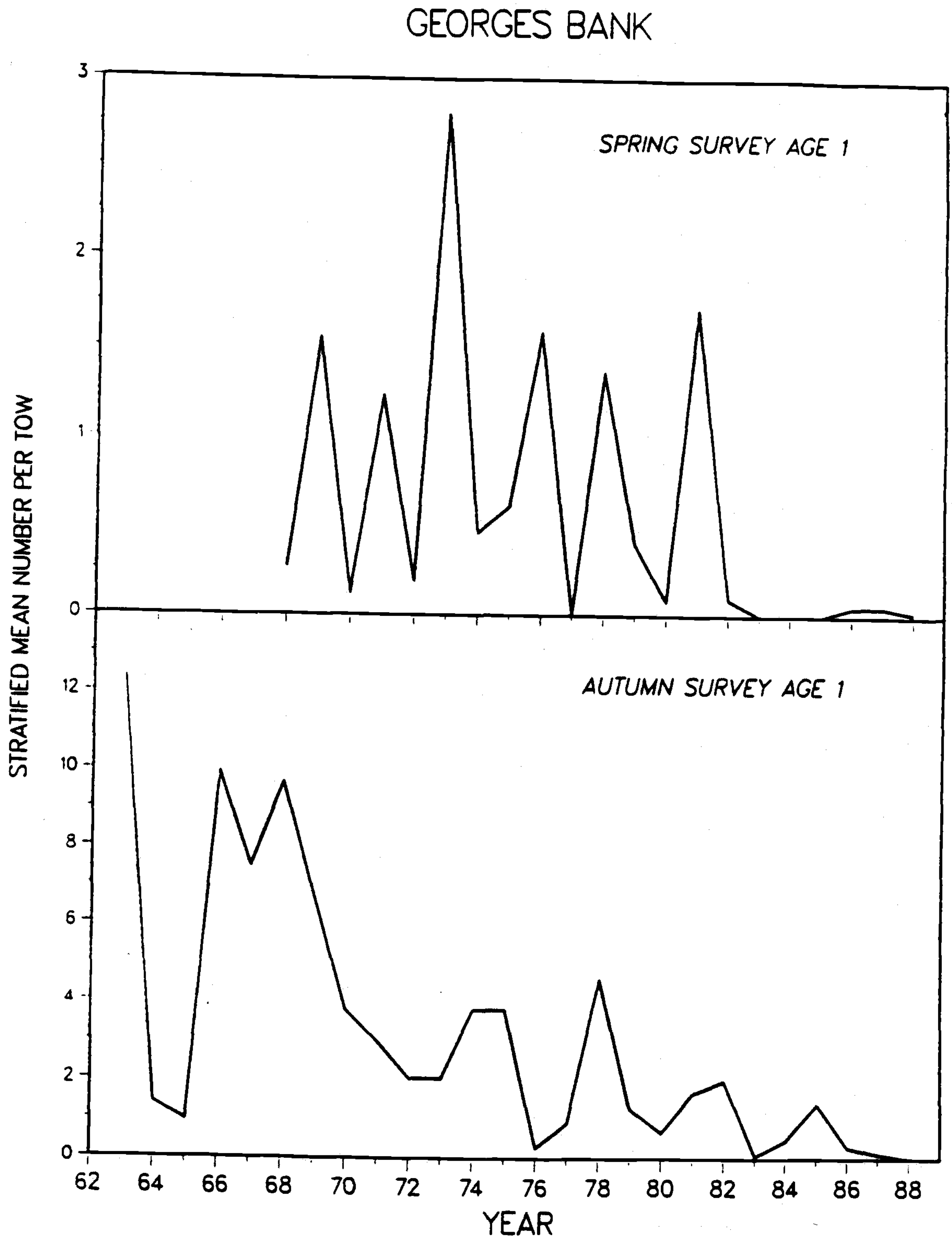


Figure 17. Stratified mean number per tow at age-1 for Georges Bank yellowtail flounder in NEFC offshore spring and autumn bottom trawl surveys, 1963-1988.

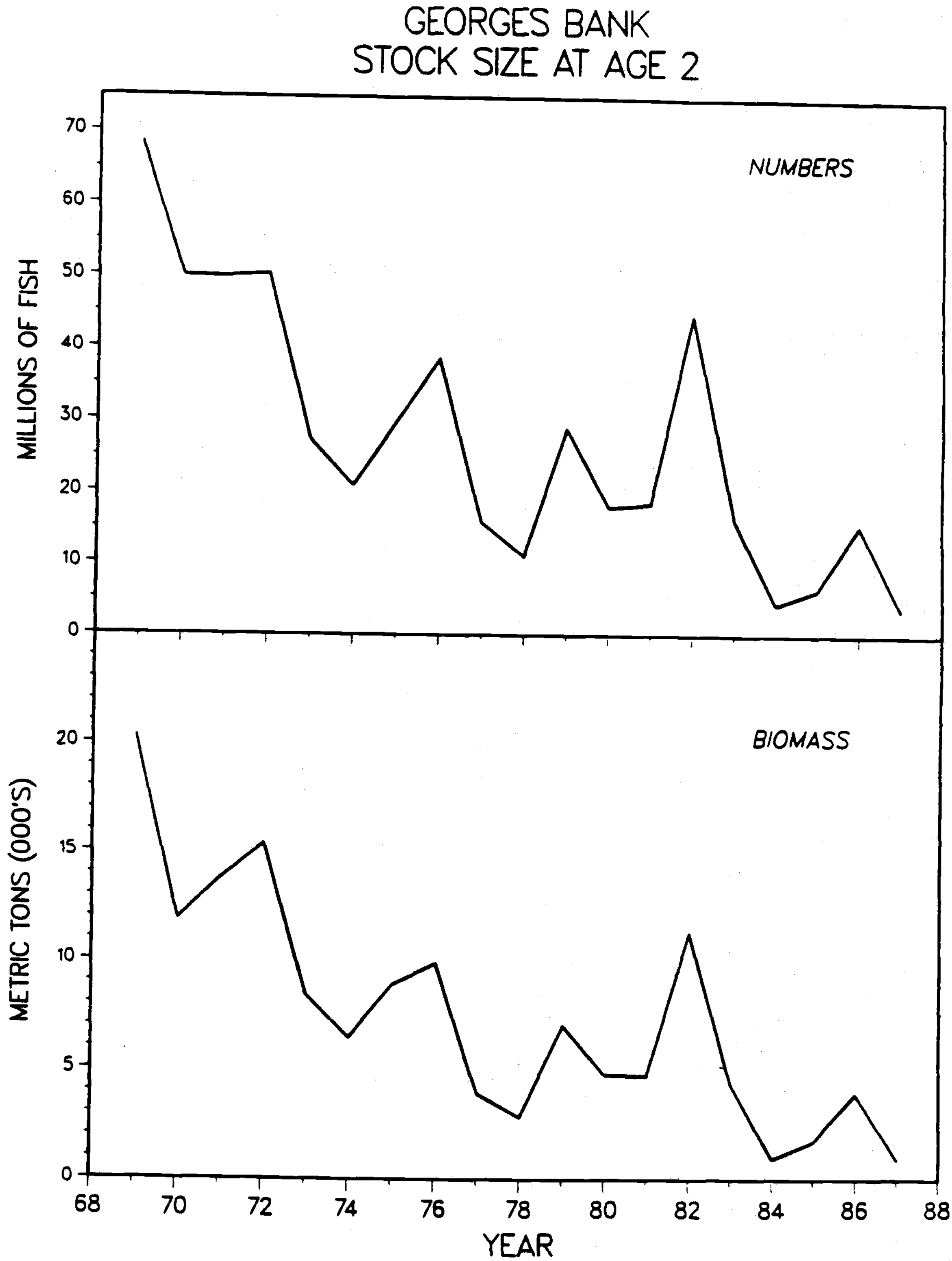


Figure 18. VPA estimated stock size at age 2 for Georges Bank yellowtail flounder (1969-1987, statistical areas 522-525) in millions of fish and thousands of metric tons.

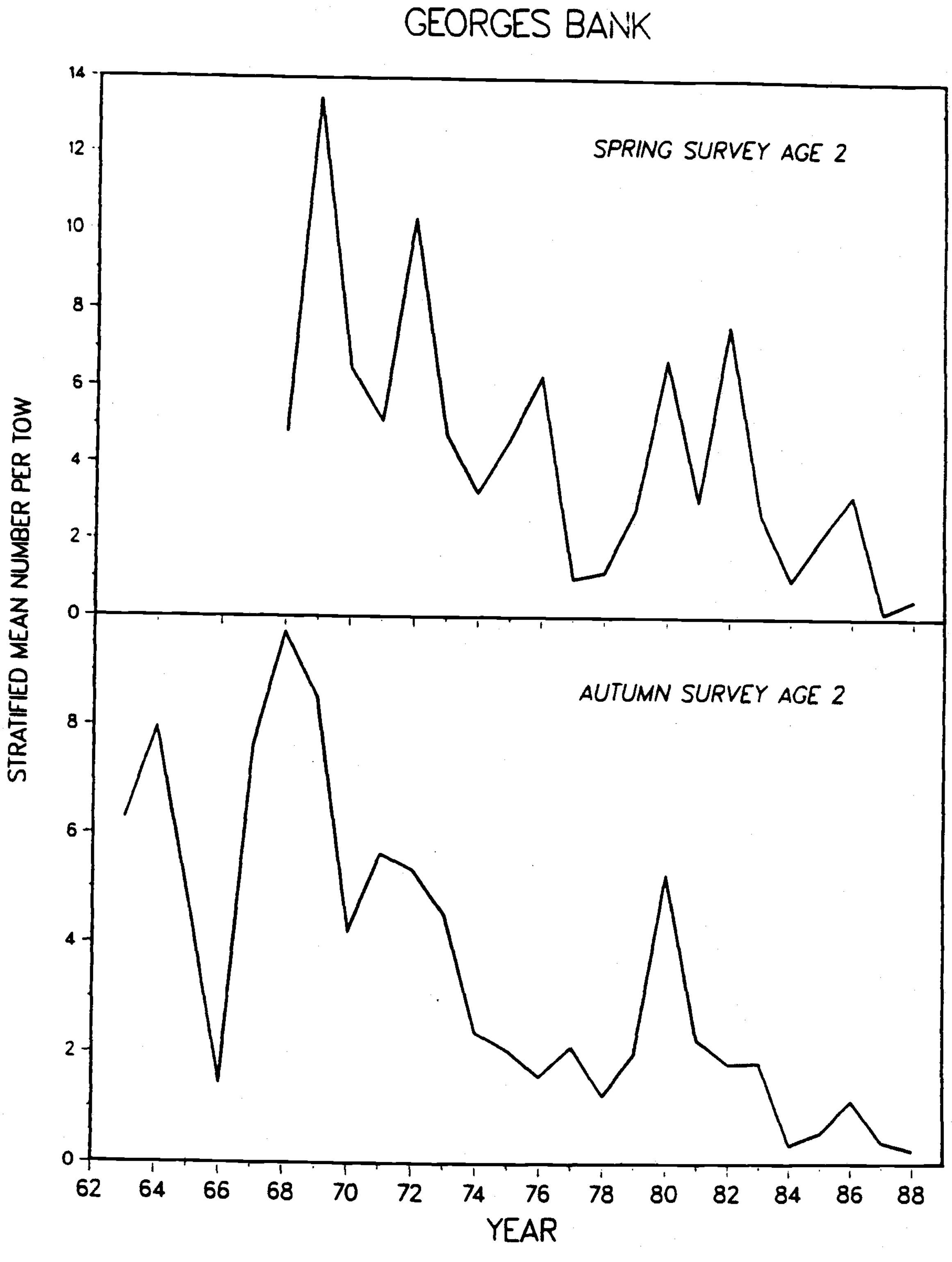


Figure 19. Stratified mean number per tow at age 2 for Georges Bank yellowtail flounder in NEFC offshore spring and autumn bottom trawl surveys, (1963-1988).

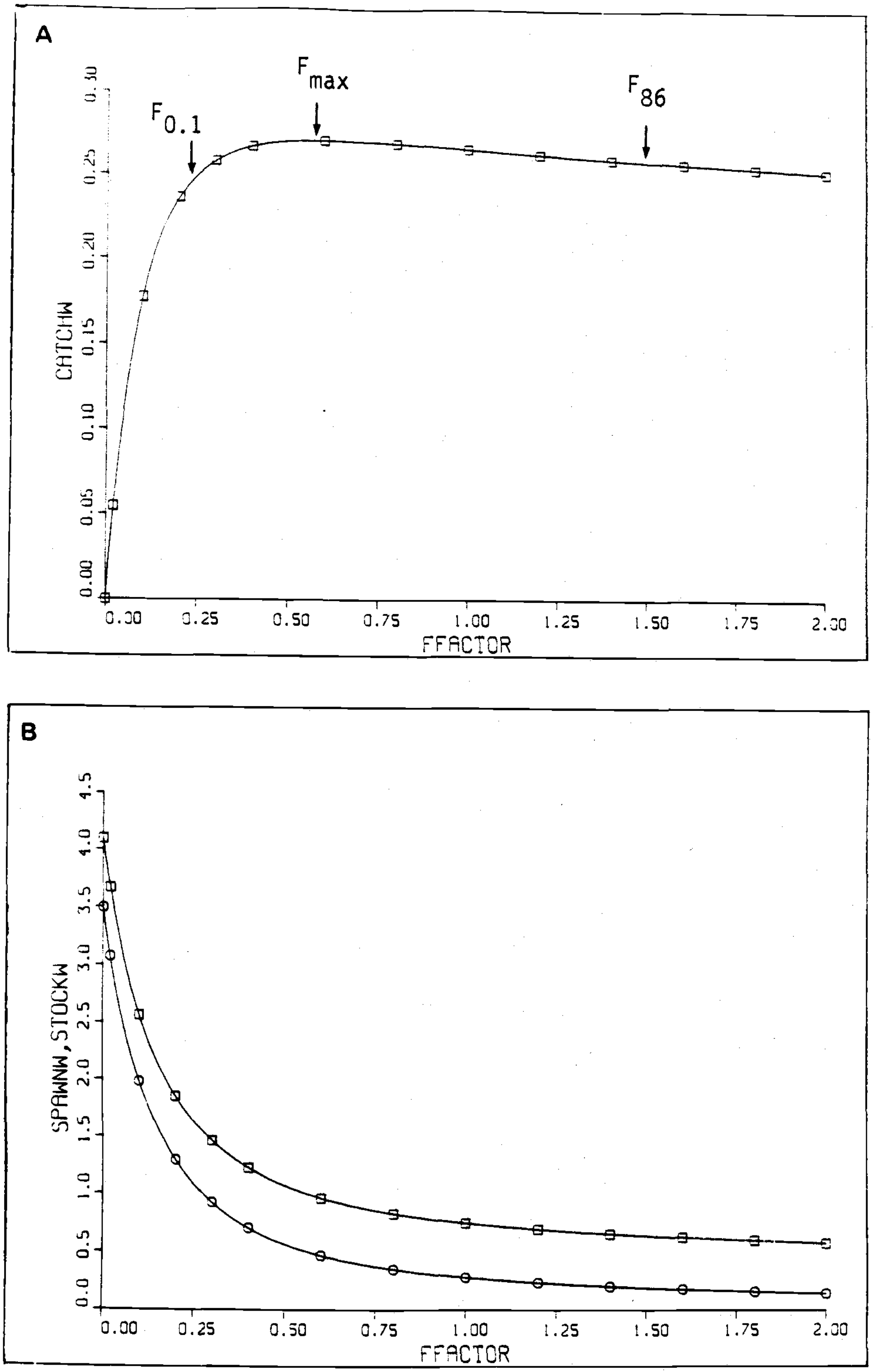


Figure 20. (A) Long-term yield per recruit; and (B) long-term total stock and spawning stock biomass per recruit relationships for Southern New England (statistical areas 526, 537-539) yellowtail flounder.

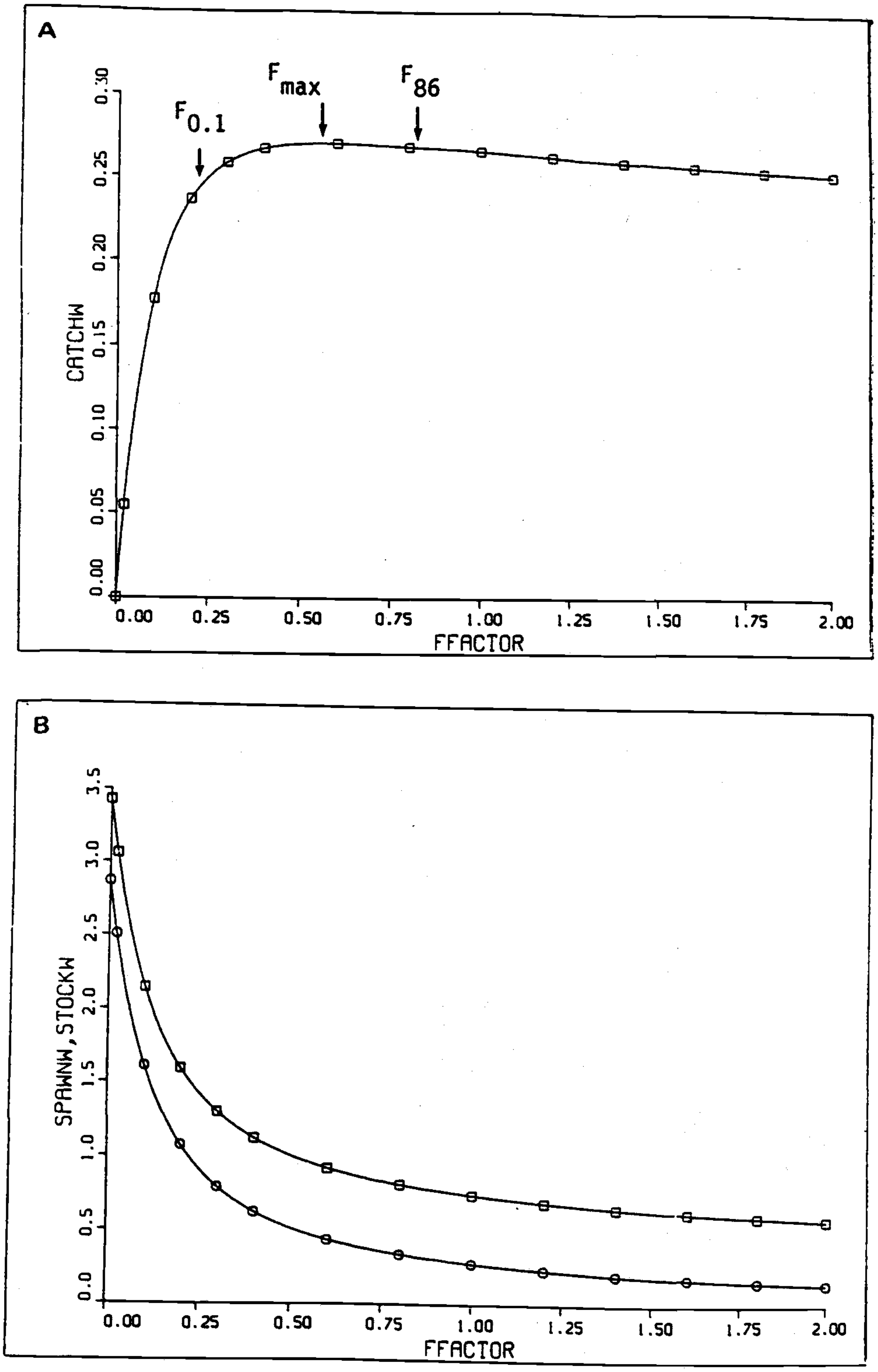


Figure 21. (A) Long-term yield per recruit; and (B) long-term total stock and spawning stock biomass per recruit relationships for Georges Bank (statistical areas 522-525) yellowtail flounder.

Table 1. Commercial catch of yellowtail flounder (000's of metric tons) from the Southern New England, Georges Bank, Mid-Atlantic, Gulf of Maine and Cape Cod areas 1960-1987 (1987 US landings only).

	SOUTHERN NEW ENGLAND					GEORGES BANK			
Year	USA	USA Discard	Indust.	Foreign	Total Catch	USA	USA Discard	Foreign	Total Catch
1960	7.8	3.2	0.5	-	11.5	4.4	1.5	-	5.9
1961	11.6	4.7	0.7	-	17.0	4.2	1.5	-	5.7
1962	13.1	5.3	0.2	-	18.6	7.7	2.7	-	10.4
1963	22.0	5.4	0.3	0.2	27.9	11.0	5.6	0.1	16.7
1964	19.0	9.5	0.5	-	29.0	14.9	4.9	-	19.8
1965	18.4	7.0	1.0	1.4	27.8	14.2	4.4	0.8	19.4
1966	14.9	5.3	2.7	0.7	23.6	11.3	2.1	0.3	13.7
1967	10.8	7.7	4.5	2.8	25.8	8.4	5.5	1.4	15.3
1968	14.3	6.3	3.9	3.5	28.0	12.8	3.6	1.8	18.2
1969	11.4	2.4	4.2	17.6	35.6	15.9	3.9	2.4	22.2
1970	13.1	4.5	2.1	2.5	22.2	15.5	2.9	0.3	18.7
1971	8.2	2.2	0.4	0.3	11.1	11.9	0.7	0.5	13.1
1972	8.2	1.8	0.3	3.0	13.3	14.2	1.7	2.2	18.1
1973	7.2	0.8	0.3	0.2	8.5	15.9	1.6	0.3	17.8
1974	6.4	0.4	<0.1	0.1	6.9	14.6	0.1	1.0	15.7
1975	3.2	0.1	<0.1	-	3.3	13.8	0.5	0.1	14.4
1976	1.6	0.1	<0.1	<0.1	1.7	11.4	0.1	<0.1	11.5
1977	2.8	0.1	<0.1	<0.1	2.9	9.5	0.2	-	9.7
1978	2.3	0.1	<0.1	-	2.4	4.5	0.2	<0.1	4.7
1979	5.4	0.3	<0.1	-	5.7	5.5	0.1	<0.1	5.6
1980	6.0	0.3	<0.1	-	6.3	6.4	0.1	<0.1	6.5
1981	4.9	0.3	<0.1	-	5.2	6.4	0.1	<0.1	6.5
1982	10.3	0.6	-	-	10.9	10.7	0.4	<0.1	11.1
1983	17.9	0.6	-	-	18.5	11.4	0.2	<0.1	11.6
1984	8.5	0.2	-	-	8.7	5.8	0.2	<0.1	6.0
1985	3.2	0.1	-	-	3.3	2.5	0.1	<0.1	2.6
1986	3.3	0.1	-	-	3.4	3.0	<0.1	<0.1	3.0
1987	1.6		-	-		2.7			

Table 1. (continued)

	MID-ATLANTIC				GULF OF MAINE			CAPE COD		
Year	USA	USA Discard	Foreign	Total Catch	USA	USA Discard	Total Catch	USA	Discard	Total Catch
1960	-	-	-	-	-	-	-	1.5	0.5	2.0
1961	-	-	-	-	-	-	-	1.8	0.6	2.4
1962	-	-	-	-	-	-	-	1.9	0.6	2.5
1963	-	-	-	-	-	-	-	3.6	1.0	4.6
1964	1.8	<0.1	-	1.8	-	-	-	1.8	0.6	2.4
1965	2.1	<0.1	-	2.1	-	-	-	1.5	0.5	2.0
1966	2.4	<0.1	-	2.4	-	-	-	1.8	0.3	2.1
1967	5.3	<0.1	-	5.3	-	-	-	1.5	0.8	2.3
1968	3.3	<0.1	-	3.3	-	-	-	1.6	0.6	2.2
1969	3.9	<0.1	0.7	4.6	0.1	<0.1	0.1	1.3	0.3	1.6
1970	4.1	<0.1	0.1	4.2	0.1	<0.1	0.1	1.2	0.4	1.6
1971	6.9	<0.1	1.0	7.9	0.1	<0.1	0.1	1.7	0.7	2.4
1972	8.8	<0.1	0.1	8.9	0.2	<0.1	0.2	1.4	0.3	1.7
1973	4.9	0.2	0.2	5.3	0.1	<0.1	0.1	1.7	<0.1	1.7
1974	1.9	<0.1	<0.1	1.9	0.1	<0.1	0.1	2.1	0.2	2.3
1975	0.7	<0.1	<0.1	0.7	0.2	<0.1	0.2	2.0	<0.1	2.0
1976	0.3	<0.1	-	0.3	0.3	<0.1	0.3	3.6	0.1	3.7
1977	0.5	<0.1	<0.1	0.5	0.2	<0.1	0.2	3.5	<0.1	3.5
1978	0.4	<0.1	-	0.4	0.4	<0.1	0.4	3.7	0.4	4.1
1979	0.5	<0.1	-	0.5	0.3	<0.1	0.3	4.2	0.5	4.7
1980	0.3	<0.1	-	0.3	0.5	<0.1	0.5	5.1	0.6	5.7
1981	0.7	0.1	-	0.8	0.4	<0.1	0.4	3.2	0.6	3.8
1982	1.3	<0.1	-	1.3	0.5	<0.1	0.5	3.1	0.4	3.5
1983	1.5	0.2	-	1.7	0.3	<0.1	0.3	1.9	0.3	2.2
1984	2.2	-	-	2.2	0.2	-	0.2	1.0	-	1.0
1985	0.15	-		0.15	0.2	-	0.2	1.0	-	1.0
1986	0.3	-		0.3	0.2	-	0.2	1.0	-	1.0
1987	0.34				0.2			1.2		

Table 1. (continued)

GRAND TOTAL

Year	USA	USA Discard	Indust.	Foreign	Total Catch
1960	13.7	5.2	0.5	-	19.4
1961	20.6	6.8	0.7	-	25.1
1962	22.7	8.6	0.2	-	31.5
1963	36.6	12.0	0.3	0.3	49.2
1964	37.5	15.0	0.5	-	53.0
1965	36.2	11.9	1.0	2.2	51.3
1966	30.4	7.7	2.7	1.0	41.8
1967	26.0	14.0	4.5	4.2	48.7
1968	32.0	10.5	3.9	5.3	51.7
1969	32.6	6.6	4.2	20.7	64.1
1970	34.0	7.8	2.1	2.9	46.8
1971	28.8	3.6	0.4	1.8	34.6
1972	32.8	3.8	0.3	5.3	42.2
1973	39.8	2.6	0.3	0.7	33.4
1974	25.1	0.7	<0.1	1.1	26.9
1975	19.9	0.6	<0.1	0.1	20.6
1976	17.2	0.3	<0.1	<0.1	17.5
1977	16.5	0.3	<0.1	<0.1	16.8
1978	11.3	0.7	<0.1	<0.1	12.0
1979	15.9	0.9	<0.1	<0.1	16.8
1980	18.3	1.0	<0.1	<0.1	19.3
1981	15.6	1.1	<0.1	<0.1	16.7
1982	27.1	1.4	-	<0.1	28.5
1983	33.1	1.3	-	<0.1	34.3
1984	17.7	0.4	-	<0.1	18.1
1985	7.0	0.2	-	-	7.2
1986	7.8	0.1	-	-	7.9
1987	6.0				

Table 2. Estimated age compostion (percent landed at age) plus total numbers of Southern New England and Georges Bank yellowtail in USA commercial landings, 1970-1986.

Year	Percent Landed at Age								Total Landed (000's)
	1	2	3	4	5	6	7	8	
				Southern New England					
1970	-	10.6	28.3	43.3	14.2	3.2	0.3	0.1	30230
1971	-	13.6	19.3	42.0	19.4	4.4	1.1	0.1	18743
1972	-	15.2	30.2	14.3	31.0	7.0	1.7	0.6	19364
1973	0.1	15.7	41.2	25.2	9.1	7.0	1.3	0.4	18068
1974	2.1	12.7	24.5	31.8	15.4	5.7	6.4	1.4	15148
1975	2.1	34.6	19.3	11.8	17.9	7.4	4.6	2.3	8071
1976	-	39.2	24.1	7.4	10.1	11.3	4.9	2.9	3572
1977	0.3	28.4	55.4	6.4	2.3	3.3	1.6	2.3	6917
1978	0.2	57.8	22.3	15.3	2.5	0.8	0.5	0.7	6030
1979	0.2	39.1	50.9	6.5	2.5	0.7	0.1	-	13177
1980	0.7	32.2	40.8	22.6	2.7	0.7	0.1	0.1	15365
1981	-	22.0	47.4	21.5	7.8	1.3	-	-	10332
1982	0.2	56.8	34.6	6.8	1.2	0.3	0.1	-	30916
1983	0.1	28.4	65.9	5.0	0.5	0.2	-	-	51016
1984	0.2	10.3	56.3	28.8	3.3	1.0	-	-	23668
1985	2.1	50.2	18.9	16.7	9.9	1.7	0.3	0.2	7892
1986	4.7	56.5	27.9	5.4	3.3	1.2	0.4	0.5	10205
				Georges Bank					
1970	0.1	15.0	40.4	27.7	11.1	3.7	1.2	0.9	29179
1971	-	9.0	40.2	32.2	11.9	4.5	1.4	0.9	21811
1972	-	12.2	39.2	30.7	13.6	3.3	0.7	0.3	28082
1973	-	10.5	41.7	30.0	12.1	4.3	0.9	0.4	30720
1974	1.1	27.9	30.4	25.0	11.0	2.5	1.4	0.5	28500
1975	0.9	52.9	23.4	10.9	7.2	2.7	1.2	0.8	29170
1976	0.1	67.2	21.8	5.4	2.1	1.7	1.1	0.6	25733
1977	0.2	36.7	49.5	8.9	2.0	1.2	0.8	0.7	18628
1978	-	26.4	44.7	21.3	5.1	1.5	0.4	0.6	7325
1979	0.2	52.7	27.5	11.2	5.8	1.2	0.9	0.5	11733
1980	-	14.6	70.5	11.2	2.7	0.8	0.1	0.1	12260
1981	-	2.9	47.5	42.2	6.1	1.2	-	-	10039
1982	0.8	50.0	31.2	13.2	4.2	0.5	0.1	-	26350
1983	0.9	27.5	60.1	8.7	2.3	0.4	0.1	-	26925
1984	2.0	14.2	32.5	36.3	12.4	1.9	0.4	0.3	13075
1985	6.6	58.6	14.8	11.8	7.2	1.0	0.1	-	5675
1986	16.7	64.4	11.5	4.4	1.9	0.7	0.3	0.1	8580

Table 3. Commercial catch (000's tons)[1], 24 hour days fished, and catch per day (000's tons)[2] of yellowtail flounder for Southern New England, Georges Bank, and Cape Cod grounds.

Year	Southern New England			Georges Bank			Cape Cod		
	Total Catch	Days Fished	Catch/ Day	Total Catch	Days Fished	Catch/ Day	Total Catch	Days Fished	Catch/ Day
1960	11.5	4.60	2.5	5.9	2.02	2.9	2.0	1.12	1.8
1961	17.0	4.85	3.5	5.7	1.82	3.1	2.4	0.91	2.6
1962	18.6	4.04	4.6	10.4	2.35	4.4	2.5	1.01	2.5
1963	27.9	5.47	5.1	16.7	3.63	4.6	4.6	1.00	4.6
1964	29.0	5.08	5.6	19.8	3.53	5.6	2.4	0.71	3.4
1965	27.8	6.61	4.2	19.4	4.68	4.2	2.0	0.70	2.8
1966	23.6	8.42	2.8	13.7	5.71	2.4	2.1	1.37	1.6
1967	25.8	6.51	4.0	15.3	4.13	3.7	2.3	1.69	1.4
1968	28.0	6.66	4.2	18.2	4.66	3.9	2.2	0.99	2.3
1969	35.6	10.78	3.3	20.9	6.71	3.1	1.6	0.68	2.5
1970	22.4	6.40	3.5	21.3	6.26	3.4	1.6	0.53	3.0
1971	12.2	3.81	3.2	15.5	6.20	2.5	2.4	0.79	3.0
1972	13.2	4.71	2.8	17.6	8.00	2.2	1.7	0.67	2.5
1973	7.8	4.11	1.9	16.8	6.96	2.4	1.7	0.89	1.9
1974	7.2	3.74	1.9	16.8	8.40	2.0	2.3	1.21	1.9
1975	3.4	2.43	1.4	14.9	8.59	1.7	2.0	1.25	1.6
1976	1.8	1.50	1.2	12.1	7.50	1.6	3.7	2.31	1.6
1977	2.8	2.00	1.4	9.7	6.70	1.4	3.5	2.42	1.4
1978	2.6	1.44	1.8	5.0	3.57	1.4	4.1	2.05	2.0
1979	6.0	3.00	2.0	6.1	3.05	2.0	4.7	2.61	1.8
1980	6.6	3.17	2.1	7.1	4.26	1.7	5.7	3.25	1.8
1981	6.2	2.59	2.4	6.9	4.16	1.6	3.8	2.30	1.9
1982	13.6	3.78	3.6	12.2	5.62	2.2	3.5	2.02	1.8
1983	20.0	6.71	2.9	12.2	5.53	2.2	2.2	1.25	1.7
1984	7.9	4.88	1.6	7.9	5.15	1.1	1.1	1.01	1.1
1985	2.7	3.36	0.8	2.5	3.31	0.7	1.0	1.30	0.7
1986	3.3	3.78	0.9	3.0	3.51	0.9	1.0	1.46	0.7
1987	1.6	2.17	0.7	2.7	3.80	0.7	1.2	1.55	0.7

1 Discard estimates not included beyond 1983.
2 Calculated for USA trawlers of 5-310 GT.

Table 4. Stratified mean catch per tow in numbers and weight (kg) for Southern New England yellowtail flounder in NEFC offshore spring and autumn bottom trawl surveys, 1963-1987.

Year	Age 0	1	2	3	4	5	6	7	8+	Total No.	Total wt. (kg)
					Spring						
1968	0.00	2.80	45.36	46.22	27.17	1.44	0.16	0.09	0.00	1123.24	32.21
1969	0.00	7.44	28.12	39.55	21.42	3.84	0.25	0.00	0.00	100.62	23.10
1970	0.00	2.15	15.24	28.93	20.38	5.98	1.55	0.33	0.14	74.70	20.28
1971	0.15	1.79	23.09	28.43	9.46	1.49	0.04	-	0.03	74.48	18.49
1972	0.00	0.84	31.38	21.26	6.64	12.69	1.92	0.44	0.00	75.17	18.55
1973	0.00	1.90	10.47	18.34	9.06	6.15	9.53	1.18	0.66	57.29	14.69
1974	0.00	1.07	4.28	3.36	3.60	2.35	0.85	1.44	0.32	17.27	5.04
1975	0.00	0.82	2.25	0.72	1.00	1.28	0.68	0.05	0.21	7.01	1.98
1976	0.00	0.04	4.70	0.75	0.38	0.43	0.38	0.19	0.09	6.96	2.45
1977	0.00	0.35	1.76	2.24	0.22	0.26	0.12	0.04	0.16	5.15	1.99
1978	0.00	4.43	14.04	2.85	1.03	0.27	0.05	0.07	0.20	22.94	5.15
1979	0.00	2.22	4.84	2.57	0.45	0.16	0.00	0.00	0.01	10.25	2.15
1980	0.00	0.54	6.21	4.73	3.90	0.42	0.15	0.02	0.04	16.01	5.95
1981	0.00	0.35	14.55	5.24	2.16	0.78	0.11	0.00	0.07	23.26	6.85
1982	0.00	1.09	22.58	13.53	3.12	0.99	0.28	0.04	0.00	41.63	10.38
1983	0.00	0.12	6.05	18.59	1.28	0.32	0.00	0.00	0.00	26.36	8.03
1984	0.00	0.00	1.36	3.73	2.20	0.51	0.23	0.00	0.00	8.03	2.85
1985	0.00	0.07	0.70	0.37	0.27	0.43	0.29	0.00	0.00	2.47	0.67
1986	0.00	0.00	6.98	2.87	0.50	0.13	0.06	0.00	0.00	10.67	2.78
1987	-	0.00	0.34	1.61	0.27	-	-	-	-	2.22	0.70
1988	-									2.76	0.69
					Autumn						
1963	0.05	16.46	15.23	13.98	4.26	0.55	0.00	0.08	0.00	50.61	16.83
1964	0.00	18.47	26.19	4.80	7.13	3.27	0.80	0.11	0.00	60.77	19.03
1965	0.26	11.63	16.90	6.20	1.77	1.73	0.21	0.04	0.00	38.74	12.68
1966	0.88	35.92	10.44	1.78	1.02	0.19	0.00	0.00	0.00	50.23	9.43
1967	0.27	18.44	25.65	11.14	1.57	0.40	0.06	0.13	0.00	57.66	14.05
1968	0.00	10.72	9.47	18.08	1.12	0.00	0.61	0.19	0.04	40.23	10.06
1969	0.00	11.88	9.74	27.48	5.47	0.12	0.04	0.04	0.00	54.77	14.39
1970	0.04	4.23	5.52	16.34	10.62	2.51	0.43	0.07	0.00	39.76	10.96
1971	0.00	6.34	10.84	6.25	15.20	2.69	0.22	0.16	0.00	41.70	9.18
1972	-	4.25	15.98	19.35	19.13	12.75	1.76	0.07	0.00	73.28	20.11
1973	0.00	1.56	1.19	1.80	1.34	1.00	0.83	0.23	0.00	7.95	2.25
1974	0.21	1.02	1.64	0.59	2.25	0.96	0.40	0.19	0.07	7.33	2.13
1975	0.00	1.67	0.50	0.19	0.23	0.22	0.00	0.09	0.00	2.90	0.71
1976	0.00	2.99	6.18	0.54	0.07	0.11	0.30	0.35	0.15	10.69	2.96
1977	0.04	1.70	2.19	0.80	0.12	0.04	0.04	0.08	0.00	5.01	1.50
1978	0.00	3.26	7.20	0.43	0.38	0.04	0.01	0.08	0.03	11.43	3.06
1979	0.00	1.73	4.42	2.40	0.37	0.04	0.04	0.00	0.00	9.00	2.57
1980	0.00	1.48	4.33	1.18	0.34	0.00	0.00	0.00	0.00	7.33	1.96
1981	0.00	3.24	9.25	1.06	1.21	0.02	0.04	0.00	0.00	14.82	3.79
1982	0.00	2.14	24.17	7.02	0.84	0.33	0.00	0.00	0.00	34.50	8.13
1983	0.00	2.61	15.93	8.17	0.70	0.08	0.00	0.04	0.00	27.53	6.51
1984	0.00	0.54	1.82	1.97	0.54	0.00	0.00	0.00	0.00	4.91	1.37
1985	-	1.20	0.53	0.17	0.16	0.00	0.00	0.00	0.00	2.06	0.44
1986	-	0.97	1.97	0.42	0.09	0.00	0.00	0.00	0.00	3.48	0.88
1987	-	1.53	0.66	0.56	0.05	0.04	-	0.04	-	2.98	0.61
1988										2.43	0.50

Table 5. Stratified mean catch per tow in numbers and weight (kg) for Georges Bank yellowtail flounder in NEFC offshore spring and autumn bottom trawl surveys, 1963-1987.

	Age									Total No.	Total wt. (kg)
Year	0	1	2	3	4	5	6	7	8+		
					Spring						
1968	0.00	0.26	4.79	5.16	0.44	0.11	0.26	0.18	0.00	11.20	3.77
1969	0.00	1.55	13.46	16.05	4.47	2.06	0.65	0.12	0.25	38.61	15.10
1970	0.00	0.12	6.46	8.55	3.66	0.83	0.18	0.09	20.07	7.16	
1971	0.00	1.23	5.09	6.73	4.97	1.08	0.33	0.14	-	19.57	6.23
1972	0.00	0.19	10.31	10.40	5.09	1.43	0.05	0.16	0.14	27.77	8.72
1973	0.00	2.80	4.73	3.43	1.54	0.59	0.25	0.03	0.03	13.40	3.97
1974	0.00	0.46	3.22	2.67	1.80	0.52	0.27	0.10	0.03	9.07	3.67
1975	0.00	0.61	4.61	1.01	0.41	0.25	0.07	0.00	0.02	6.98	2.26
1976	0.00	1.58	6.26	1.81	0.45	0.28	0.04	0.07	0.06	10.55	3.07
1977	0.00	0.00	0.98	1.62	0.57	0.09	0.02	0.00	0.00	3.28	1.35
1978	0.00	1.36	1.16	0.73	0.30	0.06	0.00	0.01	0.00	3.62	1.00
1979	0.00	0.40	2.81	0.54	0.47	0.08	0.07	0.05	0.01	4.43	1.66
1980	0.00	0.08	6.69	8.39	0.68	0.08	0.05	0.00	0.00	15.99	6.02
1981	0.00	1.71	3.07	1.09	0.36	0.13	0.03	0.00	0.01	6.40	3.12
1982	0.00	0.09	7.59	2.50	0.70	0.16	0.00	0.00	0.05	11.09	3.98
1983	0.00	0.00	2.68	4.00	0.86	0.26	0.09	0.00	0.05	7.94	3.57
1984	0.00	0.00	0.95	1.25	1.23	0.65	0.05	0.00	0.00	4.13	2.21
1985	0.00	0.00	2.13	0.21	0.28	0.15	0.00	0.00	0.00	3.00	0.99
1986	0.00	0.05	3.18	0.51	0.10	0.24	0.10	0.00	0.00	4.18	1.47
1987	0.00	0.05	0.13	0.27	0.21	0.09	0.10	-	-	0.85	0.57
1988										2.09	0.98
					Autumn						
1963	0.00	12.39	6.28	9.53	1.21	0.41	0.08	0.14	0.09	30.13	9.99
1964	0.00	1.42	7.97	6.04	4.92	2.21	0.31	0.08	0.02	22.97	10.64
1965	0.02	0.96	4.79	4.82	2.89	1.29	0.09	0.17	0.02	15.05	7.10
1966	1.17	9.93	1.46	1.40	0.67	0.10	0.04	0.00	0.00	14.77	3.12
1967	0.05	7.49	7.63	2.21	0.83	0.25	0.06	0.05	0.00	18.57	5.92
1968	0.00	9.67	9.72	4.76	0.64	0.78	0.03	0.00	0.00	25.60	8.22
1969	1.05	6.67	8.52	4.97	1.36	0.36	0.22	0.15	0.00	23.12	7.25
1970	0.78	3.77	4.21	2.58	1.60	0.37	0.05	0.01	0.00	13.37	3.88
1971	0.03	2.97	5.64	4.08	1.84	0.45	0.19	0.02	0.02	15.24	4.97
1972	0.73	2.04	5.34	3.96	1.72	0.52	0.26	-	-	14.56	4.93
1973	0.10	2.04	4.51	4.18	2.41	1.00	0.34	0.14	0.02	14.74	5.07
1974	1.01	3.79	2.35	1.24	0.87	0.38	0.20	0.11	0.00	9.95	2.86
1975	0.36	3.79	2.06	0.72	0.47	0.27	0.03	0.00	0.03	7.73	1.81
1976	0.00	0.27	1.58	0.39	0.10	0.10	0.03	0.00	0.06	2.53	1.18
1977	0.00	0.91	2.13	1.56	0.01	0.10	0.06	0.04	0.02	4.83	2.56
1978	0.04	4.59	1.24	0.75	0.39	0.13	0.01	0.00	0.02	7.17	2.15
1979	0.02	1.27	2.00	0.25	0.13	0.13	0.03	0.06	0.02	3.91	1.37
1980	0.08	0.66	5.27	5.57	0.67	0.27	0.16	0.03	0.03	12.74	6.07
1981	0.00	1.67	2.26	1.28	0.61	0.07	0.05	0.00	0.08	6.02	2.37
1982	0.00	1.99	1.82	1.27	0.35	0.07	0.00	0.00	0.00	5.50	1.77
1983	0.00	0.07	1.83	1.45	0.37	0.02	0.01	0.00	0.03	3.78	1.56
1984	0.00	0.48	0.34	0.25	0.20	0.06	0.01	0.00	0.01	1.46	4.63
1985	0.00	1.40	0.57	0.18	0.05	0.08	0.00	0.00	0.00	2.29	0.73
1986	0.00	0.29	1.15	0.36	0.08	0.00	0.00	0.00	0.00	1.88	0.85
1987	0.00	0.12	0.39	0.40	0.05	0.08	0.00	0.00	0.00	1.03	0.51
1988										0.38	0.17

Table 6. Estimated cull point (cm) for discarding unmarketable yellowtail flounder and regulated cod end mesh size (inches) in effect for US commercial fishery discard estimations.

	SOUTHERN NEW ENGLAND		GEORGES BANK	
	Cull Point	Mesh Size	Cull Point	Mesh Size
1969	31	4 1/2	31	4 1/2
1970	30	4 1/2	30	4 1/2
1971	31	5 1/8	31	5 1/8
1972	31	5 1/8	31	5 1/8
1973	29	5 1/8	31	5 1/8
1974	29	5 1/8	27	5 1/8
1975	27	5 1/8	27	5 1/8
1976	27	5 1/8	27	5 1/8
1977	28	5 1/8	27	5 1/8
1978	26	5 1/8	28	5 1/8
1979	28	5 1/8	28	5 1/8
1980	28	5 1/8	30	5 1/8
1981	28	5 1/8	31	5 1/8
1982	27	5 1/8	27	5 1/2
1983	27	5 1/8	28	5 1/2
1984	27	5 1/8	27	5 1/2
1985	27	5 1/8	27	5 1/2
1986	26	5 1/2	27	5 1/2

Table 7. Percent estimated of total US numbers landed during quarters 1 & 2 and 3 & 4 representing additional numbers discarded for each calendar year in VPA time series.

	SOUTHERN NEW ENGLAND		GEORGES BANK	
	QTRS		QTRS	
YEAR	1 & 2	3 & 4	1 & 2	3 & 4
1969	49.06	53.16	28.04	28.44
1970	44.68	38.98	32.18	27.74
1971	28.87	32.99	17.60	15.29
1972	31.83	24.47	23.24	12.56
1973	13.79	9.65	18.45	12.00
1974	9.27	5.65	2.75	8.30
1975	1.85	10.33	2.65	9.06
1976	6.43	4.83	3.29	1.51
1977	6.08	8.15	4.34	3.36
1978	3.62	3.53	4.03	15.77
1979	13.16	7.24	8.77	6.43
1980	9.94	8.52	13.48	2.57
1981	14.12	9.48	11.15	9.59
1982	12.74	5.16	3.95	7.65
1983	2.72	6.58	2.44	3.37
1984	2.04	3.71	0.10	9.38
1985	2.58	13.14	1.21	5.83
1986	4.78	6.18	2.92	1.39

Table 8. Estimated numbers (000's of fish) within components (USA commercial landings, USA commercial discard, USA industrial catch, and foreign catch) and total of the Southern New England (Statistical areas 526, 537-539) catch at age, 1970-1986.

	AGE								
Year	1	2	3	4	5	6	7	8+	Total
				USA Commercial Landings in Numbers at Age					
1970	11.5	3240.3	8597.7	13618.6	4613.6	1067.6	109.9	32.3	31291.5
1971	36.1	2455.8	3568.0	8338.6	3444.2	818.2	227.5	29.9	18918.3
1972		2725.0	5356.6	2713.3	5786.2	1525.2	411.2	173.3	18690.8
1973	28.1	2595.6	7186.8	4628.9	1718.9	1510.0	254.9	54.7	17977.9
1974	127.0	2165.8	4218.8	4832.5	2350.2	907.4	979.6	176.6	15757.9
1975	170.2	2611.1	1482.3	964.0	1615.5	639.1	401.9	201.4	8085.5
1976	37.4	1723.5	896.7	245.8	338.8	411.9	169.8	105.5	3929.4
1977	67.3	2152.8	3930.8	392.1	205.2	242.9	125.1	242.3	7358.5
1978	20.9	3208.6	1457.1	1024.8	165.7	36.0	45.5	27.7	5986.3
1979	19.0	4944.6	8252.4	671.1	426.8	96.0	23.7		14433.6
1980	118.5	4557.0	6322.9	3618.1	471.6	116.9	23.4	17.7	15246.1
1981	6.9	2733.8	6424.4	2449.9	884.9	129.0	17.5	2.0	12648.4
1982	56.4	17558.3	12715.4	1741.5	417.4	82.6	7.8	2.4	32581.8
1983	57.4	13802.6	33260.6	3347.3	375.8	128.8	35.4	7.8	51015.7
1984	45.2	2605.0	13808.7	6555.6	738.0	244.2	6.8	13.1	24016.6
1985	166.2	3960.9	887.7	1315.1	780.5	137.9	27.1	16.4	7291.8
1986	38.9	5825.8	2867.3	561.0	330.7	125.0	39.5	49.6	9837.8
				USA Commercial Discard in Numbers at Age					
1970	766.4	3439.7	7276.4	1275.1	208.3				12965.9
1971	148.6	1806.1	2417.5	1311.4	160.6				5844.2
1972	47.4	3429.8	1485.2	142.7	190.1				5295.2
1973	126.3	541.1	1093.4	242.9	87.1	15.2			2106.0
1974	163.9	693.9	311.8	64.1	14.8				1248.5
1975	313.2	97.4							410.6
1976	75.1	150.2							225.3
1977	196.5	315.3							511.8
1978	122.1	91.3							213.4
1979	220.2	1122.1	26.0						1368.3
1980	177.4	1245.1	6.4						1428.9
1981	523.4	923.9							1447.3
1982	88.9	2255.8	69.6						2414.3
1983	596.9	1764.1	51.4						2412.4
1984	138.8	351.9	145.0						635.7
1985	467.8	109.0							576.8
1986	328.2	223.4							551.6

Table 8. (Continued).

	AGE								
Year	1	2	3	4	5	6	7	8+	Total
				USA Industrial Catch in Numbers at Age					
1970	368.4	1233.4	2474.5	793.4	101.4	4.0	0.4	0.1	4975.6
1971	94.5	296.0	354.8	151.0	17.9	0.2			914.4
1972	105.1	391.2	127.5	79.3	38.2	3.2			744.5
1973	28.2	167.6	256.6	94.7	62.1	73.7	16.5	0.4	699.8
1974									0.0
1975									0.0
1976									0.0
1977									0.0
1978									0.0
1979									0.0
1980									0.0
1981									0.0
1982									0.0
1983									0.0
1984									0.0
1985									0.0
1986									0.0
				Foreign Catch in Numbers at Age					
1970	442.5	1471.9	2960.7	949.9	121.8	5.1	0.5	0.1	5952.5
1971	74.1	226.6	272.1	115.1	13.7	0.2			701.8
1972	444.8	1350.0	539.3	335.4	161.4	13.5			2844.4
1973	17.0	101.1	154.8	57.1	37.5	44.5	5.4	0.3	417.7
1974	27.8	55.7	20.4	19.4	11.0	3.6	6.0	0.9	144.8
1975	0.8	1.0	0.2	0.1	0.2				2.3
1976	3.8	6.1	0.7	0.2	0.2	0.2	0.1	0.1	11.5
1977									0.0
1978									0.0
1979									0.0
1980									0.0
1981									0.0
1982									0.0
1983									0.0
1984									0.0
1985									0.0
1986									0.0

Table 8. (Continued)

Total Catch in Numbers at Age

	AGE								
Year	1	2	3	4	5	6	7	8+	Total
1970	1588.8	9385.3	21309.3	16637.0	5045.1	1076.7	110.8	32.5	55185.5
1971	353.3	4784.5	6612.4	9916.1	3636.4	818.6	227.5	29.9	26378.7
1972	597.3	7896.0	7508.6	3270.7	6175.9	1541.9	411.2	173.3	27574.9
1973	199.6	3405.4	8691.6	5023.6	1905.6	1643.4	276.8	55.4	21201.4
1974	318.7	2915.4	4551.0	4916.0	2376.0	911.0	985.6	177.5	17151.2
1975	484.2	2709.5	1482.5	964.1	1615.7	639.1	401.9	201.4	8498.4
1976	116.3	1879.8	897.4	246.0	339.0	412.1	169.9	105.6	4166.2
1977	263.8	2468.1	3930.8	392.1	205.2	242.9	125.1	242.3	7870.3
1978	143.0	3299.9	1457.1	1024.8	165.7	36.0	45.5	27.7	6199.7
1979	239.2	6066.7	8278.4	671.1	426.8	96.0	23.7	0.0	15801.9
1980	295.9	5802.1	6329.3	3618.1	471.6	116.9	23.4	17.7	16675.0
1981	530.3	3657.7	6424.4	2449.9	884.9	129.0	17.5	2.0	14095.7
1982	145.3	19814.1	12785.0	1741.5	417.4	82.6	7.8	2.4	34996.1
1983	654.3	15566.7	33312.0	3347.3	375.8	128.8	35.4	7.8	53428.1
1984	184.0	2956.9	13953.7	6555.6	738.0	244.2	6.8	13.1	24652.3
1985	634.0	4069.9	887.7	1315.1	780.5	137.9	27.1	16.4	7868.6
1986	367.1	6049.2	2867.3	561.0	330.7	125.0	39.5	49.6	10389.4

Table 9. Estimated numbers (000's of fish) within components (USA commercial landings, USA commercial discard, USA industrial catch, and foreign catch) and total of the Georges Bank (Statistical areas 522-525) catch at age, 1969-1986.

	AGE								
Year	1	2	3	4	5	6	7	8+	Total
				USA Commercial Landings in Numbers at Age					
1969		12920.0	12917.2	8998.4	2806.6	815.0	377.2	175.2	39009.6
1970	23.4	4632.0	11885.7	8574.1	3439.3	1147.1	347.6	256.0	30305.2
1971	11.7	2578.4	8804.4	6826.9	2477.9	955.1	263.9	173.2	22091.5
1972		3461.6	10814.4	8791.1	4003.4	1025.6	208.0	87.3	28391.4
1973		4072.5	14006.0	9490.7	3407.7	1044.8	261.0	139.4	32422.1
1974	205.3	7088.9	8209.9	7306.3	3379.0	787.4	418.8	220.1	27615.7
1975	426.7	16855.9	6942.7	3391.0	2084.4	670.3	313.5	165.0	30849.5
1976	43.3	19324.9	5084.3	1347.0	533.0	432.2	288.0	147.4	27200.1
1977	36.0	6584.1	9806.0	1721.3	394.5	220.7	129.9	127.8	19020.3
1978	18.3	2193.5	3970.6	1659.7	467.9	112.0	51.6	58.7	8532.3
1979	24.4	6920.6	3395.5	1242.5	551.1	139.6	78.4	51.7	12403.8
1980		2451.6	8695.1	1321.2	323.9	87.5	3.9	10.6	12893.8
1981	7.0	1590.3	5540.9	4220.0	712.8	111.5	3.5	0.1	12186.1
1982	216.9	13213.7	7098.3	3245.8	1039.2	71.5	21.0	3.1	24909.5
1983	239.4	7670.8	16009.5	2321.7	624.8	108.2	10.5	7.7	26992.6
1984	244.2	1909.4	4244.5	4734.0	1592.0	257.2	46.8	16.7	13044.8
1985	372.7	3322.6	841.4	667.8	411.1	54.1	4.8		5674.5
1986	99.2	5798.9	985.6	380.8	166.1	58.4	21.5	10.8	7521.3
				USA Commercial Discard in Numbers at Age					
1969	2952.1	7437.5	649.3	118.9					11157.8
1970	2106.6	4618.5	2206.7	56.4					8988.2
1971	459.0	2097.9	833.1	162.3	23.0				3575.3
1972	387.4	2779.8	1182.6	249.0	87.8				4686.6
1973	414.2	3635.0	636.1	22.8					4708.1
1974	16.5	213.7	23.4						253.6
1975	1701.4	472.7							2174.1
1976	188.6	374.7							563.3
1977	450.7	227.0	16.3						694.0
1978	864.0	120.5							984.5
1979	583.9	290.7							874.6
1980	278.5	668.4							946.9
1981	400.3	140.5	9.4						550.2
1982	1410.0	265.6	9.5						1685.1
1983	72.3	699.7	39.4						811.4
1984	508.6	258.4							767.0
1985	173.8	32.6							206.4
1986	53.1	97.1							150.2

Table 9. (Continued).

	AGE								
Year	1	2	3	4	5	6	7	8+	Total
				Canadian Catch in Numbers at Age					
1969	34.8	239.8	159.5	107.5	33.1	9.5	4.7	1.8	590.7
1970	7.4	32.3	49.3	30.2	12.1	4.0	1.2	1.0	137.5
1971	3.5	35.2	72.5	52.6	18.8	7.2	1.9	1.4	193.1
1972	0.2	3.0	5.7	4.3	2.0	0.5	0.1		15.8
1973	0.3	5.0	9.5	6.2	2.2	0.7	0.2	0.1	24.2
1974									0.0
1975									0.0
1976									0.0
1977									0.0
1978									0.0
1979									0.0
1980									0.0
1981									0.0
1982									0.0
1983									0.0
1984									0.0
1985									0.0
1986									0.0
				Foreign Catch in Numbers at Age					
1969	251.2	1777.5	847.8	60.6	3.3				2940.4
1970	154.8	450.7	297.5	29.9	0.8				933.7
1971	130.4	804.9	476.5	104.7	5.7				1522.2
1972	1039.6	5601.6	2090.0	503.8	42.3	1.2			9278.5
1973	131.6	324.2	84.1	26.9	3.6	1.4			571.8
1974	180.5	161.4	56.6	27.3	5.5	3.1			434.4
1975									0.0
1976									0.0
1977									0.0
1978									0.0
1979									0.0
1980									0.0
1981									0.0
1982									0.0
1983									0.0
1984									0.0
1985									0.0
1986									0.0

Table 9. (Continued)

	AGE								
Year	1	2	3	4	5	6	7	8+	Total
				Total Catch in Numbers at Age					
1969	3238.1	22374.8	14573.8	9285.4	2843.0	824.5	381.9	177.0	53698.5
1970	2292.2	9733.5	14439.2	8690.6	3452.2	1151.1	348.8	257.0	40364.6
1971	604.6	5516.4	10186.5	7146.5	2525.4	962.3	265.8	174.6	27382.1
1972	1427.2	11846.0	14092.7	9548.2	4135.5	1027.3	208.1	87.3	42372.3
1973	546.1	8036.7	14735.7	9546.6	3413.5	1046.9	261.2	139.5	37726.2
1974	402.3	7464.0	8289.9	7333.6	3384.5	790.5	418.8	220.1	28303.7
1975	2128.1	17328.6	6942.7	3391.0	2084.4	670.3	313.5	165.0	33023.6
1976	231.9	19699.6	5084.3	1347.0	533.0	432.2	288.0	147.4	27763.4
1977	486.7	6811.1	9822.3	1721.3	394.5	220.7	129.9	127.8	19714.3
1978	882.3	2314.0	3970.6	1659.7	467.9	112.0	51.6	58.7	9516.8
1979	608.3	7211.3	3395.5	1242.5	551.1	139.6	78.4	51.7	13278.4
1980	278.5	3120.0	8695.1	1321.2	323.9	87.5	3.9	10.6	13840.7
1981	407.3	1730.8	5550.3	4220.0	712.8	111.5	3.5	0.1	12736.3
1982	1626.9	13479.3	7107.8	3245.8	1039.2	71.5	21.0	3.1	26594.6
1983	311.7	8370.5	16048.9	2321.7	624.8	108.2	10.5	7.7	27804.0
1984	752.8	2167.8	4244.5	4734.0	1592.0	257.2	46.8	16.7	13811.8
1985	546.5	3355.2	841.4	667.8	411.1	54.1	4.8	0.0	5880.9
1986	152.3	5896.0	985.6	380.8	166.1	58.4	21.5	10.8	7671.5

Table 10. Commercial Mean Weight-at-Age at the beginning of the year for Southern New England (1970-1986) and Georges Bank (1969-1986) U.S. fisheries.

Year	AGE 1	2	3	4	5	6	7	8+
				Mean Weight-at-Age Southern New England				
1970	0.097	0.253	0.357	0.405	0.486	0.590	0.666	0.775
1971	0.102	0.273	0.400	0.421	0.497	0.578	0.710	1.178
1972	0.087	0.257	0.370	0.430	0.433	0.531	0.714	0.730
1973	0.091	0.212	0.375	0.420	0.453	0.538	0.647	0.656
1974	0.089	0.237	0.344	0.434	0.474	0.494	0.486	0.582
1975	0.075	0.234	0.355	0.449	0.454	0.468	0.475	0.553
1976	0.084	0.233	0.421	0.561	0.587	0.588	0.629	0.711
1977	0.092	0.222	0.370	0.525	0.693	0.673	0.742	0.702
1978	0.059	0.193	0.374	0.515	0.680	0.688	0.688	0.562
1979	0.069	0.205	0.340	0.474	0.603	0.758	0.892	0.766
1980	0.080	0.206	0.378	0.510	0.738	0.814	1.095	0.969
1981	0.076	0.236	0.365	0.517	0.705	0.915	1.205	1.250
1982	0.112	0.198	0.322	0.465	0.639	0.765	0.956	1.000
1983	0.121	0.235	0.326	0.477	0.627	0.893	0.845	0.769
1984	0.075	0.210	0.298	0.401	0.488	0.649	1.293	0.907
1985	0.104	0.237	0.349	0.414	0.536	0.596	0.723	1.045
1986	0.081	0.221	0.307	0.447	0.545	0.577	0.799	0.840
				Mean Weight-at-Age Georges Bank				
1969	0.111	0.297	0.430	0.597	0.718	0.813	0.877	0.950
1970	0.085	0.238	0.419	0.551	0.719	0.802	1.011	1.074
1971	0.090	0.276	0.426	0.545	0.689	0.834	0.953	0.990
1972	0.115	0.306	0.413	0.508	0.599	0.757	0.709	1.228
1973	0.121	0.308	0.431	0.498	0.579	0.692	0.938	1.235
1974	0.093	0.308	0.466	0.581	0.672	0.774	0.883	0.967
1975	0.106	0.298	0.462	0.507	0.599	0.640	0.696	0.741
1976	0.068	0.256	0.528	0.661	0.767	0.863	0.816	1.100
1977	0.089	0.246	0.449	0.618	0.782	0.753	0.966	0.940
1978	0.079	0.255	0.448	0.629	0.786	0.911	0.902	1.175
1979	0.069	0.243	0.391	0.575	0.676	0.896	0.839	0.017
1980	0.083	0.266	0.467	0.639	0.849	0.992	1.293	1.218
1981	0.117	0.258	0.430	0.583	0.642	0.900	0.832	1.195
1982	0.076	0.254	0.428	0.648	0.672	1.124	1.124	1.171
1983	0.085	0.267	0.444	0.544	0.687	0.743	1.073	1.148
1984	0.062	0.221	0.356	0.517	0.631	0.878	1.022	1.124
1985	0.079	0.270	0.399	0.519	0.624	0.768	0.850	0.950
1986	0.080	0.252	0.506	0.637	0.678	0.824	0.831	1.409

Table 11. Numbers discarded at age (000's), Percent of total numbers discarded at age, and percent of total numbers caught discarded at age for Southern New England 1970-1986.

Year	1	2	3	4	5	6	7	8+	Total
				Numbers Discarded at Age (000's)					
1970	766.4	3439.7	7276.4	1275.1	208.3				12965.9
1971	148.6	1806.1	1356.8	1311.4	160.6				4783.5
1972	47.4	3429.8	1485.2	142.7	190.1				5295.2
1973	126.3	541.1	1093.4	242.9	87.1	15.2			2106.0
1974	163.9	693.9	311.8	64.1	14.8				1248.5
1975	313.2	97.4							410.6
1976	75.1	150.2							225.3
1977	196.5	315.3							511.8
1978	122.1	91.3							213.4
1979	220.2	1122.1	26.0						1368.3
1980	177.4	1245.1	6.4						1428.9
1981	523.4	923.9							1447.3
1982	88.9	2255.8	69.6						2414.3
1983	596.9	1764.1	51.4						2412.4
1984	138.8	351.9	145.0						635.7
1985	467.8	109.0							576.8
1986	328.2	223.4							551.6
				Percent of Total Numbers Discarded at Age					
1970	5.91	26.53	56.12	9.83	1.61				100.0
1971	3.11	37.76	28.36	27.42	3.36				100.0
1972	0.90	64.77	28.05	2.69	3.59				100.0
1973	6.00	25.69	51.92	11.53	4.14	0.72			100.0
1974	13.13	55.58	24.97	5.13	1.19				100.0
1975	76.28	23.72							100.0
1976	33.33	66.67							100.0
1977	38.39	61.61							100.0
1978	57.22	42.78							100.0
1979	16.09	82.01	1.90						100.0
1980	12.42	87.14	0.45						100.0
1981	36.16	63.84							100.0
1982	3.68	93.43	2.88						100.0
1983	24.74	73.13	2.13						100.0
1984	21.83	55.36	22.81						100.0
1985	81.10	18.90							100.0
1986	59.50	40.50							100.0

Table 11. Southern New England discard (cont.)

Year	AGE 1	2	3	4	5	6	7	8+	Total
	Percent Discarded of Total US Food Catch								
1970	1.73	7.77	16.44	2.88	0.47				29.3
1971	0.60	7.29	5.48	5.30	0.65				19.3
1972	0.20	14.30	6.19	0.59	0.79				22.1
1973	0.60	2.55	5.16	1.15	0.41	0.07			9.9
1974	0.96	4.08	1.83	0.38	0.09				7.3
1975	3.69	1.15							4.8
1976	1.81	3.62							5.4
1977	2.49	4.00							6.5
1978	1.97	1.47							3.4
1979	1.39	7.10	0.16						8.7
1980	1.06	7.47	0.04						8.6
1981	3.71	6.55							10.3
1982	0.25	6.45	0.20						6.9
1983	1.12	3.30	0.10						4.5
1984	0.56	1.43	0.59						2.6
1985	5.95	1.39							7.3
1986	3.16	2.15							5.3

Table 12. Total number discarded at age (000's), percent of total number discarded at age, and percent of total US number caught discarded at age for Georges Bank.

	Age								
Year	1	2	3	4	5	6	7	8+	Total
				U.S. Number Discarded at Age (000,s)					
1969	2952.1	7437.5	649.3	118.9					11157.8
1970	2106.6	4618.5	2206.7	56.4					8988.2
1971	459.0	2097.9	833.1	162.3	23.0				3575.3
1972	387.4	2779.8	1182.6	249.0	87.8				4686.6
1973	414.2	3635.0	636.1	22.8					4708.1
1974	16.5	213.7	23.4						253.6
1975	1701.4	472.7							2174.1
1976	188.6	374.7							563.4
1977	450.7	227.0	16.3						694.0
1978	864.0	120.5							984.6
1979	583.9	290.7							874.6
1980	278.5	668.4							946.9
1981	400.3	140.5	9.4						550.3
1982	1410.0	265.6	9.5						1685.1
1983	72.3	699.7	39.4						811.4
1984	508.6	258.4							767.0
1985	173.8	32.6							206.4
1986	53.1	97.1							150.3
				Percent of Total U.S. Numbers Discarded at Age					
1969	26.46	66.66	5.82	1.07					100.0
1970	23.44	51.38	24.55	0.63					100.0
1971	12.84	58.68	23.30	4.54	0.64				100.0
1972	8.27	59.31	25.23	5.31	1.87				100.0
1973	8.80	77.21	13.51	0.48					100.0
1974	6.50	84.29	9.21						100.0
1975	78.26	21.74							100.0
1976	33.48	66.51							100.0
1977	64.95	32.71	2.34						100.0
1978	87.75	12.24							100.0
1979	66.76	33.23							100.0
1980	29.41	70.58							100.0
1981	72.75	25.53	1.71						100.0
1982	83.67	15.76	0.57						100.0
1983	8.91	86.23	4.86						100.0
1984	66.31	33.69							100.0
1985	84.18	15.79							100.0
1986	35.35	64.63							100.0

Table 12. Georges Bank discard (cont.)

	Age								
Year	1	2	3	4	5	6	7	8	Total
	Percent Discarded at Age of Total U.S. Food Catch								
1969	5.88	14.83	1.29	0.24					22.24
1970	5.36	11.75	5.62	0.14					22.87
1971	1.79	8.17	3.25	0.63	0.09				13.93
1972	1.17	8.40	3.58	0.75	0.27				14.17
1973	1.12	9.79	1.71	0.06					12.68
1974	0.06	0.77	0.08						0.91
1975	5.15	1.43							6.58
1976	0.68	1.35							2.03
1977	2.29	1.15	0.08						3.52
1978	9.08	1.27							10.35
1979	4.40	2.19							6.59
1980	2.00	4.79							6.79
1981	3.14	1.10	0.07						4.32
1982	5.30	1.00	0.04						6.34
1983	0.26	2.52	0.14						2.92
1984	3.68	1.87							5.55
1985	2.95	0.55							3.51
1986	0.69	1.27							1.96

Table 13. Summary of Southern New England VPA (1970-1986) and Georges Bank (1969-1986) tuning results. Values presented are from regression equation Y = a + bx, where a = Y intercept (set at 0 throughtout for Georges Bank) and b = slope. Tuning measures include: 1) R-squared; 2) the sum of the absolute values of residuals for the last three years ($\Sigma|R_i|$), 3) the sum of the squared residuals for the last three years (ΣR_i^2), and the absolute value of the last year's residual.

* Denotes best fit (either maximization of R-squared or minimization of residuals).

SOUTHERN NEW ENGLAND

	Terminal F Value					
	0.5	1.0	1.3	1.4*	1.5	2.0
1) (Y) SVPA Total Weight vs (X) Smoothed Fall Survey Weight/tow (simple)						
b	256.63	268.04	271.07	271.68	272.23	274.85
R-squared	.7338	.7647	.7696	.7703	.7710	.7762*
$\Sigma\|R_i\|$	1065	715	610	591*	597	647
ΣR_i^2	456,358	184,260	167,839*	169,529	171,828	175,093
1986 resid	578.5	150.2	32.3	8.7*	11.2	62.7

GEORGES BANK

	Terminal F Value					
	0.8	0.9	1.0	1.1	1.5	2.0
2) (Y) SVPA Total Weight vs (X) Smoothed Fall Survey Weight/tow (forced)						
b	700.88	700.71	700.60	700.53	700.35	700.30
R-squared	.9720*	.9720*	.9720*	.9719	.9719	.9714
$\Sigma\|R_i\|$	526	490	462*	498	619	712
ΣR_i^2	101,258	100,539*	104,649	110,669	138,731	172,353
1986 resid	98.50	46.64	4.73*	30.21	123.07	198.03

Table 14. Estimates of fishing mortality (F), stock size (000's of fish), and stock biomass (metric tons) from virtual population analysis of Southern New England (1970-1986).

FISHING MORTALITY

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	0.046	0.010	0.041	0.029	0.051	0.042	0.015	0.011	0.006	0.011	0.009	0.006
2	0.390	0.189	0.302	0.341	0.723	0.774	0.227	0.484	0.176	0.401	0.405	0.154
3	0.580	0.526	0.506	0.645	1.067	1.064	0.642	1.026	0.594	0.871	0.973	1.101
4	1.129	0.591	0.542	0.768	0.973	0.686	0.492	0.654	0.847	0.608	1.334	1.478
5	1.227	0.824	0.941	0.713	1.091	1.078	0.551	1.025	0.647	1.123	1.243	1.771
6	1.061	0.658	1.078	0.713	0.931	1.051	0.931	1.092	0.489	1.023	1.181	1.708
7	1.010	0.675	0.844	0.560	1.399	1.705	0.930	0.845	0.578	0.703	0.761	0.540
8+	1.010	0.675	0.844	0.560	1.399	1.705	0.930	0.845	0.578	0.703	0.761	0.540
MEAN F	0.810	0.604	0.662	0.689	1.047	1.014	0.667	0.985	0.676	0.858	1.096	1.241
REC AGE	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+

AGE	1982	1983	1984	1985	1986
1	0.003	0.101	0.018	0.034	0.030
2	0.327	0.590	0.861	0.644	0.515
3	1.196	1.512	1.980	0.697	1.461
4	1.091	1.332	1.870	1.295	1.463
5	1.226	0.743	1.389	1.614	1.659
6	0.830	2.250	1.958	1.169	1.549
7	0.416	1.122	0.818	1.757	1.480
8+	0.416	1.122	0.818	1.757	1.480
MEAN F	1.181	1.485	1.922	1.135	1.480
REC AGE	3+	3+	3+	3+	3+

STOCK SIZE

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	39029.3	40630.7	16445.9	7762.3	7041.4	12977.3	8728.3	27808.8	24760.9	23587.3	34816.9	95730.7
2	31880.6	30525.7	32979.0	12925.9	6176.1	5478.2	10188.0	7045.3	22543.1	20146.7	19102.6	28249.0
3	52938.9	17678.4	20684.1	19969.0	7524.1	2454.3	2068.6	6649.5	3556.4	15483.6	11051.0	10433.7
4	26637.5	24276.9	8552.6	10208.6	8580.8	2119.9	693.2	891.5	1952.2	1608.4	5304.8	3420.5
5	7719.5	7053.0	11005.2	4074.1	3877.1	2654.6	874.5	347.1	379.5	685.4	716.7	1144.2
6	1785.2	1852.3	2533.7	3516.6	1634.3	1065.7	739.3	412.5	101.9	162.6	182.6	169.2
7	189.1	505.7	785.1	705.8	1411.9	527.6	305.0	238.6	113.3	51.2	47.9	45.9
8+	55.5	66.5	330.8	141.3	254.3	264.4	189.5	462.2	69.0	0.2	36.2	5.2
TOT NOS	160235.6	122589.2	93316.4	59303.6	36500.1	27541.9	23786.3	43855.7	53476.2	61725.4	71258.6	139198.5
WGHTUNAD	46512.9	34783.1	28149.8	19509.5	11882.1	6179.0	5641.3	8070.6	8592.1	12366.8	14368.2	20542.3
SPWN NOS	104104.1	65652.2	58671.7	44436.4	26134.5	11758.8	9513.3	12674.1	16562.1	27307.6	26436.5	29610.0
WGHTUNAD	38271.1	26039.9	21982.7	17277.0	10445.5	4505.4	3588.6	4686.7	4715.3	8451.0	9428.8	9671.6
3+ NOS	89325.7	51432.8	43891.4	38615.4	23282.5	9086.4	4870.0	9001.5	6172.3	17991.4	17339.1	15218.7
WGHTUNAD	34661.3	22305.3	18243.4	16062.8	9791.6	3923.8	2534.3	3948.1	2780.4	6609.2	7647.7	6600.0

AGE	1982	1983	1984	1985	1986	1987
1	46677.2	7527.6	11636.8	20780.1	13696.6	15546.2
2	77953.8	38163.1	5573.2	9358.2	16441.3	10882.4
3	19833.7	46022.3	17320.1	1929.3	4024.2	8043.0
4	2841.9	4910.7	8304.9	1957.2	786.9	764.4
5	639.0	781.3	1060.9	1048.1	439.0	149.2
6	159.4	153.5	304.3	216.6	170.9	68.4
7	25.1	56.9	13.3	35.2	55.1	29.7
8+	7.7	12.5	25.5	21.3	69.2	21.6
TOT NOS	148137.8	97627.9	44238.9	35345.9	35683.1	35504.9
WGHTUNAD	28932.6	27909.4	11305.5	6601.2	6770.1	6637.8
SPWN NOS	58608.9	68796.9	29714.4	9743.3	13030.3	14168.0
WGHTUNAD	15135.0	21974.1	9793.0	3238.5	3640.7	4052.7
3+ NOS	23506.7	51937.1	27028.9	5207.6	5545.2	9076.3
WGHTUNAD	8269.9	18030.3	9262.3	2222.1	2027.1	2973.5

STOCK BIOMASS AT AGE

AGE	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
1	3785.8	4144.3	1430.8	706.4	626.7	973.3	733.2	2558.4	1460.9	1627.5	2785.4	7275.5
2	8065.8	8333.5	8475.6	2740.3	1463.7	1281.9	2373.8	1564.1	4350.8	4130.1	3935.1	6666.8
3	18899.2	7071.4	7653.1	7488.4	2588.3	871.3	870.9	2460.3	1330.1	5264.4	4177.3	3808.3
4	10788.2	10220.6	3677.6	4287.6	3724.1	951.8	388.9	468.0	1005.4	762.4	2705.4	1768.4
5	3751.7	3505.3	4765.2	1845.6	1837.8	1205.2	513.3	240.6	258.1	413.3	528.9	806.7
6	1053.3	1070.6	1345.4	1891.9	807.3	498.7	434.7	277.6	70.1	123.3	148.6	154.8
7	125.9	359.1	560.5	456.7	686.2	250.6	191.8	177.1	77.9	45.7	52.4	55.3
8+	43.0	78.3	241.5	92.7	148.0	146.2	134.7	324.5	38.8	0.2	35.1	6.6

AGE	1982	1983	1984	1985	1986	1987
1	5227.9	910.8	872.8	2161.1	1109.4	1259.2
2	15434.9	8968.3	1170.4	2217.9	3633.5	2405.0
3	6386.4	15003.3	5161.4	673.3	1235.4	2469.2
4	1321.5	2342.4	3330.2	810.3	351.7	341.7
5	408.3	489.8	517.7	561.8	239.2	81.3
6	121.9	137.1	212.7	129.1	98.6	39.5
7	24.0	48.1	17.1	25.4	44.0	23.7
8+	7.7	9.6	23.2	22.2	58.1	18.2

Table 15. Estimates of fishing mortality (F), stock size (000's of fish), and stock biomass (metric tons) from virtual population analysis of Georges Bank yellowtail flounder (1969-1986).

FISHING MORTALITY

AGE	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	0.057	0.041	0.011	0.046	0.023	0.012	0.050	0.013	0.039	0.027	0.030	0.014
2	0.445	0.241	0.130	0.300	0.393	0.497	1.010	0.814	0.639	0.265	0.321	0.214
3	0.607	0.579	0.427	0.561	0.749	0.918	1.282	0.972	1.432	1.015	0.764	0.816
4	0.877	0.930	0.641	0.927	0.963	1.120	1.375	0.967	1.139	1.095	1.097	0.892
5	0.801	1.010	0.789	0.997	1.093	1.200	1.259	0.847	0.881	1.236	1.584	1.026
6	0.743	0.931	0.905	0.905	0.757	0.829	0.832	1.023	1.117	0.683	2.056	1.423
7	0.731	0.840	0.573	0.496	0.614	0.805	0.979	1.133	1.066	0.899	1.702	0.276
8+	0.708	0.727	0.539	0.720	0.847	1.023	1.264	0.970	1.354	1.042	0.925	0.835
MEAN F	0.708	0.727	0.539	0.720	0.847	1.023	1.264	0.970	1.354	1.042	0.925	0.835
REC AGE	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+

AGE	1981	1982	1983	1984	1985	1986
1	0.008	0.087	0.063	0.100	0.031	0.038
2	0.109	0.403	0.827	0.791	0.827	0.543
3	0.714	0.846	1.251	1.541	0.847	0.631
4	1.329	1.337	0.760	2.155	1.230	1.339
5	1.963	1.767	1.090	2.608	1.679	1.352
6	1.353	1.408	0.984	3.279	0.766	1.456
7	0.169	1.086	0.821	2.032	0.917	0.830
8+	0.976	1.030	1.167	1.977	1.101	0.831
MEAN F	0.976	1.030	1.167	1.977	1.101	0.831
REC AGE	3+	3+	3+	3+	3+	3+

STOCK SIZE

AGE	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	64565.6	63476.4	61975.9	34710.4	26084.7	36805.9	49477.0	19563.2	14036.1	36278.3	22627.5	22873.0
2	68475.9	49944.2	49906.2	50214.7	27132.8	20869.0	29781.9	38517.8	15809.3	11053.5	28897.2	17977.4
3	34975.8	35919.9	32134.7	35888.1	30465.8	15001.8	10399.0	8885.3	13969.3	6832.2	6945.8	17161.4
4	17296.7	15602.3	16489.7	17173.0	16770.0	11795.1	4905.6	2362.1	2752.3	2732.4	2027.3	2649.2
5	5617.3	5893.2	5042.0	7112.9	5564.6	5241.0	3151.6	1015.9	735.6	721.2	748.2	554.1
6	1714.5	2064.5	1757.4	1876.2	2148.1	1526.7	1292.5	732.7	356.7	249.7	171.6	125.7
7	802.9	668.0	666.1	582.3	621.7	824.7	545.5	460.4	215.7	95.6	103.3	18.0
8+	380.4	542.3	458.2	185.5	265.7	372.8	248.7	257.9	186.7	99.4	77.5	20.7
TOT NOS	193829.2	174110.8	168430.3	147743.0	109053.4	92437.1	99801.8	71795.4	48061.8	58062.2	61598.3	61379.5
WGHTUNAD	59362.6	48080.2	48056.3	49224.6	38615.1	29486.8	24690.0	19514.6	14339.2	11461.5	13289.8	17031.3
SPWN NOS	96911.6	87657.1	83439.7	88830.7	70168.5	46418.9	37062.9	33400.7	26523.5	17539.0	25143.5	30236.8
WGHTUNAD	42133.3	36849.0	35690.7	37576.5	31332.0	22927.3	15134.3	13224.4	11161.1	7271.7	8219.6	12774.9
3+ NOS	60787.7	60690.2	56548.1	62818.0	55835.9	34762.2	20542.9	13714.3	18216.4	10730.4	10073.7	20529.1
WGHTUNAD	31858.4	30798.0	28704.3	29867.2	27101.9	19636.2	10570.5	8323.7	9200.9	5776.8	4706.5	10350.8

AGE	1981	1982	1983	1984	1985	1986	1987
1	54862.9	21645.2	5621.6	8754.5	19580.0	4549.5	1466.2
2	18482.9	44600.6	16252.2	4320.3	6488.7	15539.6	3586.0
3	11878.1	13569.9	24403.5	5819.4	1603.0	2322.5	7391.9
4	6211.0	4760.6	4768.7	5719.8	1020.8	562.8	1011.7
5	889.2	1346.8	1023.8	1825.4	543.0	244.3	120.8
6	162.7	102.3	188.3	281.8	110.2	82.9	51.8
7	24.8	34.4	20.5	57.6	8.7	41.9	15.8
TOT NOS	92511.8	86065.0	52290.7	26799.5	29354.3	23364.6	13659.7
WGHTUNAD	20654.3	22931.2	19125.7	8007.8	4899.0	6112.1	5565.3
SPWN NOS	30331.5	42576.4	38623.9	16180.8	7217.5	11091.4	10426.9
WGHTUNAD	12055.0	15592.3	16461.1	7000.5	2520.5	3772.1	4993.2
3+ NOS	19165.9	19819.2	30416.9	13724.7	3285.6	3275.5	8607.5
WGHTUNAD	9466.7	9957.6	14308.5	6510.3	1600.2	1832.1	4544.3

STOCK BIOMASS AT AGE

AGE	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	7166.8	5395.5	5577.8	3991.7	3156.2	3422.9	5244.6	1330.3	1249.2	2866.0	1561.3	1898.5
2	20337.3	11886.7	13774.1	15365.7	8356.9	6427.6	8875.0	9860.6	3889.1	2818.6	7022.0	4782.0
3	15039.6	15050.4	13689.4	14821.8	13130.8	6990.9	4804.3	4691.5	6272.2	3060.8	2715.8	8014.4
4	10326.1	8596.9	8986.9	8723.9	8351.5	6853.0	2487.1	1561.3	1700.9	1718.7	1165.7	1692.9
5	4033.2	4237.2	3473.9	4260.6	3221.9	3522.0	1887.8	779.2	575.3	566.8	505.8	470.5
6	1393.9	1655.7	1465.7	1420.3	1486.5	1181.7	827.2	632.3	268.6	227.5	153.8	124.7
7	704.1	675.4	634.8	412.9	583.2	728.2	379.7	375.7	208.4	86.2	86.7	23.2
8+	361.4	582.4	453.6	227.8	328.2	360.5	184.3	283.7	175.5	116.8	78.8	25.2

AGE	1981	1982	1983	1984	1985	1986	1987
1	6419.0	1645.0	477.8	542.8	1546.8	364.0	117.3
2	4768.6	11328.6	4339.3	954.8	1751.9	3916.0	903.7
3	5107.6	5807.9	10835.1	2071.7	639.6	1175.2	3740.3
4	3621.0	3084.9	2594.2	2957.2	529.8	358.5	644.5
5	570.9	905.0	703.4	1151.8	338.8	165.7	81.9
6	146.4	115.0	139.9	247.4	84.6	68.3	42.6
7	20.6	38.7	22.0	58.9	7.4	34.8	13.2
8+	0.2	6.1	14.0	23.3	0.0	29.5	21.8

Table 16. Southern New England. Imput F, M, maturity, and mean weight in catch and stock values for Yield per Recruit analysis. Output reference values (Fo.1 and Fmax) and output catch, stock, and spawning stock per recruit values at vavarious F levels.

AGE	Exploitation Pattern	Natural Mort. Pattern (M)	Mean Weight in Catch & Stock (kg)	Maturity Ogive
1	0.0212	0.2	0.1820	0.000
2	0.4376	0.2	0.2630	0.599
3	1.0000	0.2	0.3370	0.876
4	1.0384	0.2	0.4460	1.000
5	1.1683	0.2	0.5780	1.000
6	1.2262	0.2	0.6790	1.000
7	1.0000	0.2	0.8760	1.000
8	1.0000	0.2	0.9120	1.000

Fishing Mortality (F)	Yield Per Recruit	Stock Biomass Per Recruit	Spawning Stock Biomass Per Recruit
0.000	0.000	2.882	2.419
0.020	0.043	2.589	2.131
0.100	0.140	1.843	1.400
0.200	0.187	1.372	0.944
0.210 Fo.1	0.196	1.346	0.919
0.300	0.204	1.115	0.699
0.400	0.210	0.958	0.550
0.545 Fmax	0.211	0.824	0.426
0.600	0.212	0.780	0.385
0.800	0.210	0.683	0.297
1.000	0.208	0.623	0.243
1.200	0.207	0.582	0.206
1.400	0.205	0.551	0.180
1.600	0.204	0.528	0.160
1.800	0.204	0.509	0.144
2.000	0.203	0.494	0.131

Table 17. Georges Bank. Imput F, M, maturity, and mean weight in catch and stock values for Yield per Recruit analysis. Output reference values (Fo.1 and Fmax) and output catch, stock, and spawning stock per recruit values at various F levels.

AGE	Exploitation Pattern	Natural Mort. Pattern (M)	Mean Weight in Catch & Stock (kg)	Maturity Ogive
1	0.0378	0.2	0.222	0.000
2	0.4919	0.2	0.311	0.599
3	1.0000	0.2	0.464	0.876
4	1.2569	0.2	0.596	1.000
5	1.4679	0.2	0.702	1.000
6	1.3655	0.2	0.816	1.000
7	1.0000	0.2	0.832	1.000
8	1.0000	0.2	1.062	1.000

Fishing Mortality (F)	Yield Per Recruit	Stock Biomass Per Recruit	Spawning Stock Biomass Per Recruit
0.000	0.000	3.425	2.867
0.020	0.055	3.061	2.507
0.100	0.177	2.150	1.612
0.200	0.236	1.597	1.075
0.211 Fo.1	0.249	1.421	0.957
0.300	0.258	1.304	0.793
0.400	0.267	1.128	0.626
0.584 Fmax	0.269	1.028	0.534
0.600	0.271	0.928	0.441
0.800	0.269	0.818	0.341
1.000	0.266	0.746	0.279
1.200	0.263	0.696	0.235
1.400	0.260	0.657	0.204
1.600	0.257	0.627	0.179
1.800	0.255	0.603	0.160
2.000	0.252	0.583	0.144

Table 18. SOUTHERN NEW ENGLAND Predicted catch (mt) for the given year and stock size projections (mt) for the beginning of the following year at various levels of fishing mortality. Predicted 1987 recruitment from regression of NEFC fall survey stratified mean number of age 1's per tow vs. VPA estimated age 1's in stock (1970-1986). VPA estimated age 1's in stock averaged (1983-1986) for 1988-1990 annual predicted recruitment.

PROJECTION A

YEAR	F		CATCH		SB	SSB
'87	0.475		1645.3	'88	8694.8	5810.1
'88	0.175		903.0	'89	10915.0	8086.6
	F89		1989		1990	1990
'89	0.210	F0.1	1501.5		12482.9	9709.5
"	0.545	Fmax	3398.2		10405.8	7687.2
"	0.1		749.4		13312.6	10519.7
"	0.175	F88	1269.9		12738.0	9958.5
"	0.2		1436.1		12555.0	9779.8
"	0.3		2065.7		11862.5	9104.5
"	0.4		2643.4		11229.4	8487.9
"	0.5		3173.8		10650.2	7924.6
"	0.6		3239.5		9556.1	6847.6
"	0.8		4521.3		9189.3	6508.3
"	1.0		5250.6		8406.7	5752.8
"	1.2		5870.7		7746.8	5118.3
"	1.4		6399.9		7188.8	4584.0
"	1.6		6853.0		6715.5	4132.9
"	1.8		7242.5		6312.7	3751.0
"	2.0		7578.6		5968.8	3426.5

Table 19. SOUTHERN NEW ENGLAND Predicted catch (mt) for the given year and stock size projections (mt) for the beginning of the following year at various levels of fishing mortality. Predicted 1987 recruitment from regression of VPA estimated age 1's in stock (1970-1986) vs. NEFC fall survey stratified mean numbers per tow at age 1. Three lowest values in time series averaged for 1988-1990 annual recruitment estimates.

PROJECTION B

YEAR	F		CATCH		SB	SSB
'87	0.475		1645.3	'88	8079.5	5810.1
'88	0.175		897.8		9261.0	7464.6
	F89		1989		1990	1990
'89	0.210	F0.1	1398.4		9732.2	8126.3
"	0.545	Fmax	3147.6		7816.7	6242.5
"	0.1		699.2		10503.9	8886.6
"	0.175	F88	1183.4		9969.2	8359.7
"	0.2		1337.7		9799.1	8192.2
"	0.3		1921.0		9157.5	7560.5
"	0.4		2454.2		8573.1	6985.6
"	0.5		2941.9		8040.6	6462.4
"	0.6		3388.7		7555.3	5986.0
"	0.8		4170.8		6709.1	5156.7
"	1.0		4828.4		6004.3	4467.6
"	1.2		5382.2		5416.2	3894.2
"	1.4		5829.5		4917.5	3409.3
"	1.6		6202.9		4501.0	3005.6
"	1.8		6583.2		4166.0	2682.6
"	2.0		6870.4		3874.3	2402.2

Table 20. GEORGES BANK Predicted catch (mt) for the given year and stock size projections (mt) for the beginning of the following year at various levels of fishing mortality. Predicted 1987 recruitment from regression of VPA estimated age 1's in stock (1969-1986) vs. NEFC fall survey stratified mean numbers per tow at age 1. VPA estimated age 1's in stock averaged (1983-1986) for 1988-1990 annual predicted recruitment.

PROJECTION A

	F		CATCH		SB	SSB
'87	0.925		2789.0	'88	3443.1	2382.8
'88	1.2		1859.7	'89	3625.0	1987.0
	F89		1989		1990	1990
'89	0.211	F0.1	445.7		5818.5	3886.8
"	0.584	Fmax	1088.2		5089.8	3230.9
"	0.2		424.1		5843.1	3909.0
"	0.4		792.1		5425.1	3531.7
"	0.6		1112.3		5062.7	3205.9
"	0.8		1391.5		4747.8	2924.1
"	1.0		1635.6		4473.8	2680.0
"	1.2	F88	1849.6		4234.7	2468.1
"	1.4		2037.7		4025.6	2283.7
"	1.6		2203.5		3842.4	2123.0
"	1.8		2350.1		3681.5	1982.6
"	2.0		2480.1		3539.8	1859.8

Table 21. GEORGES BANK Predicted catch (mt) for the given year and stock size projections (mt) for the beginning of the following year at various levels of fishing mortality. Predicted 1987 recruitment from regression of VPA estimated age 1's in stock (1969-1986) vs. NEFC fall survey stratified mean numbers per tow of age 1's. Three lowest values in the time series averaged for 1988-1990 annual predicted recruitment.

PROJECTION B

	F		CATCH	SB	SSB
'87	0.925		2789.0	3147.8	2382.8
'88	1.25		1867.0	2636.0	1556.3
	F89		1989	1990	1990
'89	0.211	F0.1	340.3	4021.0	2755.5
"	0.584	Fmax	825.9	3478.4	2260.1
"	0.2		323.8	4039.4	2772.4
"	0.4		602.9	3727.1	2486.7
"	0.6		843.9	3458.3	2241.8
"	0.8		1052.7	3226.3	2031.5
"	1.0		1234.0	3025.7	1850.5
"	1.2		1391.9	2851.9	1694.4
"	1.25	F88	1428.1	2812.1	1658.8
"	1.4		1529.7	2700.8	1559.5
"	1.6		1650.5	2569.3	1442.7
"	1.8		1756.6	2454.5	1341.3
"	2.0		1850.1	2353.9	1253.1

Table 22. GEORGES BANK Predicted catch (mt) for the given year and stock size projections (mt) for the beginning of the following year at various levels of fishing mortality. Predicted recruitment for 1987 from regression of VPA estimated age 1's in stock (1969-1986) vs. NEFC fall survey stratified mean numbers per tow at age 1. Predicted 1987 recruitment also assumed for 1988-1990 annual predictions.

PROJECTION C

	F		CATCH	SB	SSB
'87	0.925		2789.0	2716.8	2382.8
'88	1.3		1852.5	1218.2	950.8
	F89		**1989**	**1990**	**1990**
'89	0.211	F0.1	190.9	1420.4	1126.4
"	0.584	Fmax	453.6	1142.9	859.9
"	0.2		181.8	1430.0	1135.7
"	0.4		334.6	1268.4	980.2
"	0.6		463.1	1132.9	850.3
"	0.8		571.6	1019.3	741.7
"	1.0		663.2	923.8	650.7
"	1.2		740.9	843.4	574.4
"	1.3	F88	775.2	808.0	541.0
"	1.4		806.9	775.5	510.3
"	1.6		863.2	718.1	456.3
"	1.8		911.2	669.5	410.8
"	2.0		952.5	628.1	372.3

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