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REVIEW AND ASSESSMENT OF THE SUMMER FLOUNDER (PARALICHTHYS DENTATUS) FISHERY IN THE NORTHWEST ATLANTIC

BY

Michael J. Fogarty

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Signature Vaugh C Anthony

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National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

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INTRODUCTION

The summer flounder, Paralichthys dentatus, is distributed in the Northwest Atlantic from Nova Scotia to Florida, occurring primarily in the Middle Atlantic (i.e. Cape Cod to Cape Hatteras) region (Leim and Scott 1966; Gutherz 1967). Summer flounder are exploited by both commercial and recreational fishermen from late spring through early autumn while located in coastal and estuarine areas and by commercial trawlers on the outer continental shelf during winter. Preliminary USA commercial landings of summer flounder in NAFO[1] subareas 5 and 6 in 1980 were 11,500 mt, a 21% decrease over the 1979 level of 14,500 mt and a 25% increase over the 1975-1979 average yield of 9,210 mt (NAFO 1980, 1981; ICNAF 1975-1979). Estimated recreational landings in 1979 were 8,626 mt (National Marine Fisheries Service 1980).

Summer flounder migrate to the outer continental shelf in autumn and return to coastal locations in spring (Westman and Neville 1946, Poole 1962, Homer and Lux 1962, Murawski 1970, Lux and Nichy 1980).

Spawning occurs during the fall migration (Murawski and Festa 1975) at water temperatures ranging from 12°-19°C (Smith 1973). Migratory behavior and spawning progress from north to south, presumably in response to declining water temperature and changes in photoperiod, beginning in October in the northern segment of the range and extending to January-February in southern areas (Smith 1973). Summer flounder are serial spawners with a relatively protracted reproductive season (Morse, in press). Larvae are transported to coastal and estuarine areas by prevailing water currents (Williams and Deubler 1968). Post-larvae develop within estuaries and protected embayments; although summer flounder are apparently euryhaline, growth is optimal in high salinity water (Williams and Deubler 1968; Powell

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[1]North Atlantic Fishery Organization (replaced the International Commission for the Northwest Atlantic Fisheries, ICNAF).

SUMMARY

Relative abundance indices available from commercial, recreational and survey sources consistently indicate significant recovery of the summer flounder population following low abundance levels noted during 1968-1972. All relative abundance measures peaked during 1974-1976 and subsequently declined slightly in the latter part of the last decade. USA commercial landings in 1979 reached 14,500 mt in NAFO Subareas 5 and 6, the highest yield on record, possibly reflecting large scale increases in effort in the southern winter trawl fishery. Landings subsequently declined to 11,500 mt in 1980. Estimated recreational landings in 1979 were 8,626 mt; reduced estimates of recreational catch relative to previous surveys may be due to improved survey design.

Growth parameters derived for each sex indicate females attain significantly greater asymptotic size than males. Differences in longevity were also noted, maximum ages in commercial and survey samples during 1976-79 were 7 and 12 years for males and females respectively.

Mortality estimates based on analysis of tag recapture experiments conducted off southern New England and New Jersey indicated F levels ranging from 0.24-0.62. A more recent experiment conducted off North Carolina provided lower estimates of fishing mortality, even after adjustment for apparent tagging mortality of small ($\leq$30 cm TL) fish.

Catch curve analysis of survey and commercial samples collected during 1976-1979 indicated instantaneous total mortality rates of approximately 1.0. Assuming M = 0.2, current fishing mortality rates are on the order of 0.80.

Yield per recruit analyses clearly indicate growth overfishing. Assuming an age at entry of 2 years and M = 0.2, F_{max} values for males and females were 0.31 and 0.19 respectively; corresponding $F_{0.1}$ levels were 0.20 and 0.16.

Analysis of the effect of varying growth parameters by ±10% indicated only minor variation in optimal fishing mortality rates, suggesting that uniform management strategies may not adversely affect yield from stock componets which differ in growth rates.

Projected equilibrium yield based on mean recruitment levels of 40-45 x 10^6 fish (at age 1) ranged from 17,000-20,000 mt.

and Schwartz 1977). Poole (1966) suggested that Pamlico Sound and Chesapeake Bay are the primary nursery grounds for summer flounder, however, larvae have been collected in ichthyoplankton surveys off southern New England (Herman 1963, Smith 1973) and New Jersey (Festa 1974). Juveniles have also been reported in northern estuaries (Pearcy and Richards 1962; Festa 1974).

Morse (in press) determined the mean size at maturity for male and female summer flounder to be 25 cm and 32 cm in total length respectively based on samples collected throughout the Middle Atlantic Bight during NMFS spring and autumn bottom trawl surveys from 1974-79. Samples collected off New Jersey indicated a minimum size at maturity of 37 cm for females (Murawski and Festa 1976). Smith (1969) reported minimum sizes at maturity of 31 cm and 39 cm in total length for males and females respectively in Delaware Bay. There is evidence of latitudinal differences in mean size at maturity (Morse[2]); however, marked differences in size composition with latitude, possibly due to northerly migration of larger individuals, may contribute to this result.

Summer flounder are piscivorous, although invertebrates, predominantly crustaceans and molluscs, comprise an important component of the diet (Smith and Daiber 1977, Poole 1964, Powell 1974).

Analyses of meristic and morphometric characters for fish collected in the Middle and South Atlantic Bights indicate differences in summer flounder stock structure (Ginsberg 1952; Smith and Daiber 1977; Wilk et al. 1980). Smith (1973) further suggested that two discrete spawning stocks exist within the Middle Atlantic Bight based on egg and larval distribution patterns.

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[2]W. W. Morse, National Marine Fisheries Service, Sandy Hook Laboratory, personal communication.

However, Smith and Daiber (1977) were unable to detect significant differences in meristic counts between fish collected from Delaware and Chesapeake Bays. Wilk et al. (1980) reported that summer flounder collected throughout the Middle Atlantic Bight were statistically similar; evidence of mixing between Middle and South Atlantic groups was most notable in the North Carolina area. An analysis of morphometric data conducted by the State-Federal Summer Flounder Scientific and Statistical Committee (unpublished) indicated significant differences between fish collected off New York-New Jersey and others collected south of Cape Hatteras. Summer flounder obtained immediately north of Cape Hatteras could not be reliably classified as a discrete group, however, the number of specimens available for analysis was small. A recent North Carolina mark-recapture study (Gilliken[3]) indicated that summer flounder migrate northward along the coast in spring, principally to Chesapeake Bay, demonstrating that seasonal intermixture of northern and southern contingents does occur. Possible implications of stock inter-mixture relative to yield and management strategies are examined in this review.

A Fishery Management Plan (FMP) is currently being developed by the State-Federal Summer Flounder Scientific and Statistical Committee for the Mid-Atlantic Fishery Management Council.

FISHERY TRENDS

Commercial Fishery

The commercial fishery for summer flounder is conducted during May-October in coastal and near-shore waters by trawlers typically less than 15 m in length (Widerstrom 1959, June and Reintjes 1957, Reintjes and Roithmayr 1960);

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[3] J. Gilliken, North Carolina Division of Marine Fisheries, personal communication.

a small pound net fishery contributes to inshore catches (Perlmutter 1959), particularly in North Carolina (Wolff 1978). During winter, summer flounder are harvested on the outer continental shelf. The offshore winter trawl fishery off the Virginia Capes and North Carolina has assumed increasing importance since its inception in the late 1920's (Pearson 1932, Nesbit and Neville 1935, Eldridge 1962).

Total USA commercial landings of summer flounder in NAFO Subareas 5 and 6 declined from an average of 4,707 mt during 1963-66 to 1,669 mt in 1969 (Figure 1). Landings subsequently increased gradually during 1970-1976 to 10,757 mt and remained relatively stable during 1977-78, averaging 8,669 mt (Table 1; ICNAF Statistical Bulletins, Vols 13-28). Provisional landings in 1979 were 14,500 mt (NAFO 1980), the highest on record and 70% increase over the 1974-1978 mean yield of 8,554 mt. Preliminary landings declined to an estimated 11,500 mt in 1980 (NAFO 1981).

Increased provisional landings in 1979 and 1980 were primarily attributable to increases in Subarea 6. Provisional landings in SA 6 during 1979-80 averaged 11,775 mt, an 89% increase over the 1974-78 mean yield of 6,232 mt. In contrast, landings in SA 5 declined slightly during 1979 and decreased sharply in 1980 relative to the 1974-78 average of 2,322 mt (Table 1). Increased landings in SA 6 may be due, in part, to increased levels of effort in the southern winter trawl fishery. The number of vessels participating in this fishery increased during 1976-79 by 125% over the 1965-75 mean level of 64 vessels (Fishery Statistics of the United States 1965-1975; Fisheries of the United States 1976-79). DuPaul and Baker (1978) further reported an increase in vessel size (Gross Registered Tonnage) in the Virginia trawl fishery, implying an increase in fishing power in the fleet.

Reported landings of summer flounder by foreign fishing vessels have been relatively minor, averaging 128 mt during 1965-79. Catches by distant water fleets were taken exclusively by the Union of Soviet Socialist Republics during 1965-73 (Table 1). Landings by USSR vessels did not exceed 904 mt and averaged 201 mt. Since 1975 Ireland, Spain, and Italy have taken combined incidental catches of up to 52 mt. Since the implementation of the Fishery Management and Conservation Act (FCMA) in 1976, no allocations (other than by-catch) of summer flounder have been assigned to foreign nations.

Recreational Fishery

Estimates of the recreational catch of summer flounder were available from national and regional marine angler surveys conducted in 1965, 1970, 1974, and 1979 (Deuel and Clark 1968, Deuel 1973, Deuel[4] and National Marine Fisheries Service 1980). A national recreational fishing survey conducted in 1960 did not distinguish between summer and winter flounder (Clark 1962) and therefore was not utilized in this analysis. Creel census surveys were conducted off Virginia during 1955-1962 (Richards 1965), in Great South Bay, NY, during 1957-1960 and 1965-1966 (Schaefer 1966), in Great Bay, NJ, during 1967-1978 (Festa 1977, 1979, Himchak 1979), and off the New Jersey coast in 1978 (Christensen and Clifford 1979).

Estimated recreational catch derived from national and regional surveys ranged from 8,626 - 15,830 mt and comprised from 41.2 to 77.3% of total landings (Table 2). The reduced estimate of recreational catch in 1979 (8,626 mt) may reflect improvements in survey design and methodology; landings data in the 1979 survey were obtained through combined on-site and telephone interviews

[4]Deuel, D. G. National Marine Fisheries Service, Resource Statistics Division, Washington, DC, personal communication.

while previous surveys were based on telephone interview which relied on angler recall for periods ranging from 2 months (1974 survey) to 1 year (1960, 1965, and 1970 surveys). Hiett and Worrall (1977) reported that fishermen overestimated total catch by 32.6-123.17% after recall periods of 15-60 days, implying that survey designs with lengthy recall intervals may provide overestimates of recreational catch.

Creel census surveys conducted in New York, New Jersey, and Virginia provide indicators of trends in the summer flounder recreational fishery for restricted time periods and geographical locations. Catch per angler trip ranged from 2.6 to 9.5 fish during 1955-1962 for anglers aboard charter boats operating off the eastern shore of Virginia (Figure 3; Richards 1965). Schaefer (1966) reported catch rates ranging from 4.0 to 6.8 fish per angler trip in Great South Bay, NY, during 1957-1960 (Figure 3). Similar trends in CPUE are evident for both data sets in years for which comparisons are possible. Interviews in the Great South Bay study were not restricted to charter boats, possibly accounting for lower catch rates than those reported by Richards (1965). Catch per effort for anglers aboard charter boats is consistently higher than that of fishermen utilizing private or rental boats, presumably due to the skill of the charter-boat captains (Briggs 1962, Festa 1979). Sharply lower catch rates were evident in Great South Bay in 1966 and 1967, paralleling trends in the commercial fishery (Figure 3). Creel census indices (no. per trip) available for Great Bay, NJ, declined from 0.6 in 1967 to 0.3 in 1970 and gradually recovered to 3.8 fish per trip in 1975 (Festa 1979). Catch rates subsequently declined to 2.2 per trip in 1978 (Himchak 1979). The slightly higher 1978 estimate of 3.2 fish per trip reported by Christensen and Clifford (1979) was restricted to charter boat catches off the New Jersey coast; the Great Bay creel census did not include charter boats.

Recreational CPUE estimates derived for Great Bay, N.J. appear to follow trends in commercial landings of summer flounder in SA 5 when lagged by one year (Figure 3). A lag term of one year was used in this analysis since the sport fishery depends highly on newly recruited year classes (Poole 1961; Festa 1979) while the commercial fishery operates on a broader age distribution. However, both time series were significantly ($p \approx .05$) autocorrelated and no significant correlation between recreational catch-per-effort and commercial landings was detected after adjustment for serial correlation according to Quenouille (1952). It should be noted that use of commercial landings as an index of abundance implies a relatively constant expenditure of effort; changes in effort levels during the time series may introduce additional variability.

Commercial Catch-Per-Unit-Effort

Nominal effort statistics (standard 24 hr days fished) and individual trip landings data derived from NMFS interview and weighout records were utilized to examine CPUE trends for summer flounder during 1967-1980. Geographical coverage of the sample interview data is concentrated in NAFO SA 5; accordingly, the derived index is not representative of conditions throughout the entire Middle Atlantic Bight. The CPUE index was based on interview records in which summer flounder comprised $\geq$5% of the total landed weight. Trip records in which less than 5% of the catch was composed of summer flounder were considered to reflect strictly incidental catches. Analysis was further restricted to tonnage class 2 vessels (5-50 GRT) to eliminate difficulties in effort standardization for larger vessels which are characterized by higher fishing power and increased fishing range.

Catch per-day declined from 0.6 mt/day in 1967 to 0.4 mt/day in 1970, the lowest CPUE index in the time series (Figure 2). The CPUE index gradually increased to 1.2 mt/day in 1974 and subsequently declined to a relatively stable level averaging 0.9 mt/day during 1975-80.

SURVEY BIOMASS INDICES

A stratified random bottom trawl survey has been conducted in autumn by NEFC since 1967 in water depths ranging from 27 to 365 mm on the continental shelf between Cape Hatteras and Nova Scotia. Autumn surveys during 1963-1966 sampled from New Jersey to Nova Scotia. Surveys have also been carried out in spring since 1968. Strata are defined by depth zone and geographical location (Figure 4) and are intended to represent relatively homogeneous sampling units. Further details on sampling design and methods are provided by Grosslein (1969) and Clark (1979).

A standard '36 Yankee' trawl has been employed in all autumn trawl surveys and in spring surveys conducted from 1968 to 1972. A high-rise '41 Yankee' trawl has been used in spring surveys since 1973. Both trawls are equipped with roller gear (30-46 cm) and a 1.25 cm cod end liner. Fishing power coefficients and species specific conversion factors for these trawls are given in Sissenwine and Bowman (1978). The fishing power of the '41 Yankee' trawl is consistently higher for all flounder species and accordingly, summer flounder catch rates for spring surveys since 1973 were adjusted to reflect increased catchability with this trawl. Summer flounder conversion factors were 1.23 and 1.31 for catch in numbers and weight respectively (Sissenwine and Bowman 1978). Some caution in utilizing these conversion factors for summer flounder is necessary since some assumptions of the analysis were apparently not met (Sissenwine and Bowman 1978). The conversion factors are consistent, however, with the ratio of footrope lengths of the 41 and 36 trawls (1.25) implying that differences in calculated fishing power of the trawls for summer flounder may be a simple function of the trawl dimensions.

The spring survey biomass index (stratified mean catch per tow, kg) for the entire survey area increased from 0.11 kg during 1968-1972 to an average of 0.83 kg from 1974-77 and subsequently declined to 0.45 kg during 1978-80 (Figure 5). Stratified mean catch per tow increased in 1980 to 0.40 kg

over the 1979 index of 0.17. Spring survey indices are considered to provide more consistent indicators of trends in relative abundance due to the availability of summer flounder on the outer continental shelf during late winter-early spring (see Seasonal Distribution).

The autumn bottom trawl survey index for the entire survey area remained at relatively low levels during 1963-72, averaging 0.25 kg, and then increased during 1974-77 to a mean of 0.94 kg. The autumn index subsequently declined to an average of 0.39 kg during 1978-80. The 1980 index declined by 24% from the 1979 level of 0.51 kg. Similar trends were evident in stratified mean number per tow (Figure 5).

Both spring and autumn survey indices indicate a general recovery from low population levels observed during 1968-72 to peak levels from 1974-76 with a subsequent slight decline in apparent abundance during the latter part of the last decade.

Spring biomass indices (kg/tow) for the entire survey area were significantly correlated with commercial landings in NAFO areas 5 and 6 ($r = 0.98$; $p < 0.5$) after adjustment for autocorrelation. Due to sharply increased effort in the southern winter trawl fishery during 1978-80, data for this period were not included in this analysis. Significant correlation between the spring survey biomass index and the commercial CPUE index for tonnage Class 2 vessels in southern New England was also detected ($r = 0.67$; $p = 0.05$). The serial correlation coefficient for the commercial CPUE index was not significant ($p > 0.05$) obviating adjustment in tests of significance (Quenouille 1952).

Middle Atlantic

The spring biomass index for the Middle Atlantic region (strata 61-76) averaged 0.30 kg from 1968-72 and increased to a mean of 1.03 kg during 1974-77. Stratified mean catch per tow declined sharply in 1979 to 0.34 kg but recovered to 0.77 kg in 1980 (Table 3). Parallel trends were evident in

stratified mean number per tow (Table 4).

The autumn survey index ranged from 0.04-2.01 kg during 1967-73 and averaged 0.74 kg. Stratified mean catch per tow increased sharply to 2.92 kg in 1975 and then subsequently declined to 0.51 kg during 1976-80 (Table 5).

The decline in both spring and autumn indices during 1979-80 supports the inference that increased landings in SA 6 during this period was due to increased effort levels rather than increased abundance.

Southern New England

Spring biomass indices for the southern New England region (strata 1-12) remained at extremely low levels during 1968-72 before increasing to 1.44 kg from 1974-77; stratified mean catch per tow declined to 0.20 and 0.45 kg in 1979 and 1980 respectively (Table 3).

The autumn biomass index for southern New England declined sharply from 0.93 kg in 1964 to an average of 0.17 during 1968-72. Following the general recovery noted throughout the Middle Atlantic Bight, the autumn index increased to 1.36 kg from 1974-77 and declined to 0.65 kg during 1978-80 (Table 5).

Georges Bank

Summer flounder were not present in trawl survey catches on Georges Bank (strata 13-25) prior to 1973 in either fall or spring and catch rates since 1973 have remained at low levels relative to Middle Atlantic and Southern New England strata, averaging just 0.17 kg and 0.06 kg during 1973-80 in autumn and spring surveys respectively. Summer flounder were not obtained in the 1979 spring survey on Georges Bank and the 1980 index of 0.06 kg remained at a low level; fall survey stratified mean catch increased to 0.29 kg in 1980 over the corresponding 1979 index of 0.12 kg (Tables 3 and 5).

Survey Variability

Coefficients of variation computed for survey indices for each area differ among strata sets and with each area (Table 3-6). Coefficients of variation were consistently higher on Georges Bank and were also highest for each area during periods of low apparent abundance. Summer flounder at the extremes of the geographical range may be particularly vulnerable to environmental fluctuations, resulting in variable survival rates and/or changes in distribution patterns. Mean coefficients of variation for each strata set and season ranged from 27% to 63% and from 30% to 68% for catch in numbers and weight respectively, implying that proportional changes in abundance of less than approximately ±50% may not be detected with high probability, a result consistent with the observations of Grosslein (1971).

Seasonal Distribution

Summer flounder undertake well defined seasonal movements characterized by an autumn migration from inshore locations to the outer continental shelf and a return to coastal sites in spring (Westman and Neville 1946; Hamer and Lux 1962; Poole 1962; Murawski 1970; Lux and Nichy 1980). A residual northeasterly trend in movements was detected in tagging experiments conducted off New Jersey (Murawski 1970) and southern New England (Lux and Nichy 1980). Sissenwine et al. (1979) indicated that summer flounder are distributed between the 8-16°C isotherms during spring and between 12-28°C during autumn.

Summer flounder are distributed along the outer continental shelf in early spring, particularly in the Middle Atlantic region (Figure 7). These results are consistent with tagging experiments indicating distribution of summer flounder along the 100-200 m isobaths in late winter-early spring (Poole 1961,

Murawski 1970, Lux and Nichy 1980). Summer flounder typically begin the inshore migration in April and by May-June most have completed the shoalward movement.

Annual variations in the timing of migratory activity may directly affect the availability of summer flounder during NMFS groundfish surveys. Prior to the autumn migration, summer flounder are generally located in coastal areas and estuaries and are not available to NMFS survey gear. Any delay in movements from coastal locations could reduce availability of summer flounder during NEFC autumn bottom trawl surveys, resulting in underestimation of survey abundance indices. A warming trend during 1970-1976 (Davis 1979) followed by declining mean annual bottom water temperatures in the latter part of the last decade (Nickerson and Wright 1980) may have directly affected migratory patterns. The offshore migration is presumably keyed to declining water temperature and changes in photoperiod in autumn.

Examination of the distribution pattern of pre-recruit ($\leq$30 cm TL) summer flounder indicated a striking absence of small fish in northern areas (Figure 7). Both spring and autumn surveys indicated a concentration of small summer flounder south of 39° latitude. Poole (1966) suggested that the primary sources of summer flounder recruitment were the protected inshore bays and estuaries of Virginia and North Carolina, particularly Chesapeake Bay and Pamlico Sound. Survey distribution data tend to support this hypothesis and also imply a northerly trend in movements in larger fish with time, a result previously noted by Murawski (1970) based on analysis of tag returns.

GROWTH

Parameters of the von Bertlanaffy growth equation were determined for summer flounder collected during NMFS spring and autumn bottom trawl surveys using the weighted least squares method of Tomlinson and Abramson (1961). Age interpretation was based on a total of 1,889 scale samples taken from summer flounder obtained during 1976-1979. Scales were impressed in laminated plastic and examined at a magnification of 40X. Prior summer flounder age and growth analyses were based on examination of otoliths (Poole 1961, Eldridge 1962; Smith and Daiber 1977); these studies differed in interpretation of age at first distinct annulus formation. Ages were adjusted to reflect time of capture relative to an assigned average January 1 birthdate (e.g., a 2 yr. old fish collected in spring was assigned an age of 2.3 years). Growth equations were derived separately by sex and comparisons between parameter estimates for each sex were made using the homogeneity X^2 text of Rao (1973).

Female summer flounder attained a significantly larger asymptotic size (L_∞) than males ($X^2 = 47.5$; d.f. = 1; $p = .005$; Table 7), a result consistent with previous analyses (Poole 1961, Smith and Daiber 1977, Powell 1974, Eldridge 1962, Richards 1970). No significant differences were found between Brody growth coefficients (k) ($X^2_1 = 0.170$; $p > .05$). No comparisons between estimates of the parameter t_o were attempted since the properties of this parameter in uniquely defining a solution to the model often assume greater statistical than biological importance (Gallucci and Quinn 1979).

Previous estimates of L_∞ for female summer flounder ranged from 88 cm - 94 cm TL (Smith and Daiber 1977, Richards 1970). Henderson (1979) provided an estimate of L_∞ of 92 cm TL (sexes combined) based on analysis of commercial samples from the Georges Bank - southern New England region. Bigelow and

Schroeder (1953) reported a maximum verified length of 94 cm TL. The estimate of L_∞ (73 cm TL) derived for males in the present study exceeds previously reported estimates of 62 cm (Smith and Daiber 1977) and 60.7 cm (Richards 1970) based on localized inshore collections.

Values of the growth constant (k) determined for both females and males were lower than previous estimates based on analyses of inshore populations (Smith and Daiber 1977, Richards 1970) possibly due to a greater representation of younger, faster growing fish in inshore areas.

MORTALITY

Tag Data

Maximum likelihood estimates of the instantaneous rate of fishing mortality (F) were derived by the method of Paulik (1963) based on tagging experiments conducted off southern New England (Lux and Nichy 1980), off New Jersey, during 1960-61 and 1966-67 (Murawski 1970) and off North Carolina in 1973-1974 (J. Gillikin, personal communication). Petersen disc tags were used in each experiment with the exception of the 1960-61 New Jersey operations in which Atkins tags were employed (Murawski 1970); both Atkins and Petersen disc tags were used in the 1961 experiments (Table 8). Recapture data for the southern New England and New Jersey experiments were grouped into 365 day intervals for analysis. Tag recoveries for North Carolina releases were grouped into 90 day intervals for analysis since comparatively few fish were at large for over one year. A total of 143 fish captured within 10 days of release were apparently not randomly distributed with respect to the untagged population and were not included in this analysis. An additional 51 tags were recovered with insufficient information on date of recapture to

be used in mortality estimation. The total effective number of released individuals was therefore recalculated to account for immediate recaptures (adjusted for expected survival in this initial 10 day period) and unusable returns (adjusted for survival based on the mean time at liberty for fish with known recapture dates).

Estimated fishing mortality rates for two experiments conducted off southern New England were 0.48 and 0.62 for Nantucket Sound and Pt. Judith releases respectively; recovery rates were 40.8% for Nantucket Sound and 50% for Pt. Judith. Chang and Pacheco (1975) provided slightly different mortality estimates for this data set, possibly due to different methods of calculation. A total of 6,669 summer flounder were tagged in four experiments off New Jersey during 1960-1967 with an overall recovery rate of 28%. Estimates of F ranged from 0.24-0.58 in these experiments (Table 8). The estimated fishing mortality rate for the North Carolina taggings, 0.11, was low relative to previous tagging experiments and apparently not indicative of true mortality rates. Non-reporting of tags may have contributed to the low return rate (J. Gillikin, personal communication). Tag induced mortality cannot be discounted as an explanation for the low percentage of returns and an examination of the size distributions of released and recovered fish indicated a disproportionately low recovery rate for fish <30 cm TL. Accordingly, the data were reanalyzed following procedures noted above, however, only fish larger than 30 cm TL at release were considered. Estimated fishing mortality rate increased to F = 0.24 but remained low relative to previous experiments.

Examination of the seasonal pattern of tag recoveries for experiments conducted in southern New England and New Jersey clearly indicate the influence of migratory activity and the seasonal distribution of fishing effort on tag returns. Summer flounder were tagged in Nanatucket Sound and Block

Island Sound immediately prior to the offshore autumn migration (Lux and Nichy 1980). Return rates declined sharply after the initial 30 day interval for Block Island Sound releases while recoveries remained uniformly low for Nantucket Sound fish during the first 90 days at large (Figure 8). Returns subsequently increased in both experiments as fish became available to the offshore winter trawl fishery (January - April) and again after 270 days at large, following the inshore migration when the fish were vulnerable to inshore trawlers and recreational fishermen. Of the total number of tag returns, approximately 2% of the Nantucket Sound and 6% of the Block Island Sound recoveries were reported by recreational fishermen.

Similar trends in recovery patterns are evident for fish tagged and released in September - October 1960 off Cape May and Sandy Hook, New Jersey (Figure 8). Subsequent tagging experiments in New Jersey were initiated in June and July when the fish were immediately available to intensive angler effort. In marked contrast to the southern New England experiments, 25-60% of the total tag returns were attributable to recreational fishermen in the New Jersey experiments (Murawski 1970).

Total Mortality

Age composition of survey and commercial catch of summer flounder sampled during 1976-1979 was employed to estimate survival rates (S) and the instantaneous rate of total mortality (Z) by the method of Chapman and Robson (1960) and Robson and Chapman (1961). Catch curves were constructed by sex for summer flounder obtained during NEFC spring and autumn groundfish surveys for each of four years with available age data and for combined data (Table 9). Age-length keys derived for commercial samples collected in southern New England during 1976-1979 were also utilized in catch curve analyses for each year of collection. For both survey and commercial data, successive age at full recruitment values were employed until no significant differences (X^2 test;

p >0.01) were found between Heincke's survival estimate and the minimum variance estimator of Robson and Chapman (1961).

Estimates of Z derived from survey age composition varied with year of sample collection and by sex (Table 9). Total mortality ranged from 0.67-1.35 for females and from 0.87-2.85 for males. The mortality estimate for males collected in 1978(2.85) appears unreasonably high and may be due to sampling variability.

To reduce the effect of variable year class strength, age composition data were pooled over years of collection. Calculated mortality rates for females and males were 0.93 and 1.11 respectively. The higher mortality estimates for males is of interest since it has been suggested that the absence of male fish older than age 7 may be due to higher natural mortality rates (Poole 1966, Change and Pcaheco 1976). Henderson (1979) reported estimates of Z for summer flounder ranging from 0.53-1.42.

Estimates of Z for age-length samples collected from commercial sources during 1976-79 exhibited higher variability than those derived using survey data (Table 9). Possibly reflecting variations in year class strength (Figure 10) which are accentuated by high levels of fishing mortality and dependence of the commercial fishery on recruiting year classes. Total mortality estimates derived from commercial data ranged from 0.91-2.26. Adequate estimates of annual fishing effort were not available to adjust commercial catch-at-age data.

YIELD PER RECRUIT

Yield per recruit was evaluated using the incomplete beta function solution to the Beverton-Holt yield equation (Paulik and Gales 1964) since isometric growth could not be assumed. Parameter estimates of the model were based on the above growth equations and length-weight equations (Wilk et al. 1978) by sex. The instantaneous rate of natural mortality (M) was assumed to be 0.2 (Change and Pacheco 1975; Henderson 1979), the effect of varying natural mortality rates was also examined. A sensivitivy analysis was employed to determine the effect on yield and optimal fishing mortality rates of systematically varying the parameters k and L_∞ by ±10%.

Summer flounder are fully recruited to the fishery at ages 2-3 (Poole 1966; Chang and Pacheco 1975). Maximum yield per recruit for females (0.55 kg) occurs at an F_{max} level of 0.19 assuming an age at entry to the exploited phase (t_c) of 2 years (Figure 11); the corresponding $F_{0.1}$ level (Gulland and Boerema 1973) is 0.16. Increasing age at entry to 3 years results in an increase in maximum yield per recruit to 0.63 kg at an optimal level of fishing mortality (F_{max}) of 0.25. An increase in t_c to 4 years results in a further increase to 0.713 kg (F_{max} = 0.35; Figure 11). Optimal age at entry to the fishery ranges from 5-7 years assuming a range in F of 0.3-0.7 (Figure 12). Calculated F_{max} values for male summer flounder ranges from 0.32-0.66 as t_c increases from 2-4 years (Figure 13). At age entry of 2 years, $F_{0.1}$ = 0.20. Optimal age at entry ranges from 4-5 years as F increases from 0.3-0.5 (Figure 14).

Summer flounder are currently managed under a system of minimum legal size limits administered by individual states. Connecticut, New York, and New Jersey prohibit the taking of summer flounder less than 35.6 cm (14") TL, however, recreational anglers are presently exempted from this regulation in New Jersey. Minimum size limits of 30.5 cm (12") TL and 28 cm (11") TL are currently in effect in Virginia and North Carolina, respectively. Expected yield per recruit under minimum legal size limits of 25.4 - 38.1 cm (10"-15") TL was evaluated at two levels of fishing mortality. Assuming F = 0.5, yield per recruit ranged from 0.31-0.42 kg and from 0.44-0.63 kg for males and females respectively (Table 10); at F = 0.75, yield per recruit increased from 0.27 kg to 0.42 kg for males and from 0.36 kg to 0.58 kg for females (Table 10).

Increasing natural mortality rates results in a decrease in yield per recruit and an increase in F_{max} (Table 11).

The effect of varying the von Bertalanffy parameters k and L_∞ by $\pm$ 10% was examined in an attempt to determine possible consequences of managing the fishery under uncertainty regarding stock intermixture. Seasonal intermixing of the northern and southern groups is known to occur based on tagging results (Gillikin, personal communication), however, the relative contribution of each in the area of mixing cannot currently be determined.

Systematic variation of the parameters resulted in substantial changes in yield per recruit for both males and females (Tables 12 and 13). Maximum yield per recruit ranged from 0.32 to 0.88 kg for females and from 0.18 to 0.50 kg for males. Values of F_{max}, however, remained relatively stable ranging from 0.18 - 0.21 for females and from 0.31 - 0.33 for males (Tables 12 and 13). If growth rates among possible stock components vary within the ranges examined, management measures may be devised which are relatively insensitive to differences in growth.

Widely differing growth rates between males and females necessitated treating the sexes separately in these analyses; however, the fishery operates on combined sexes and appropriate management strategies must be devised accordingly. Alternative management options include setting target fishing mortality or age at entry levels based on relative contribution of each sex to the catch or managing on the basis of optimal fishing mortality (or age at entry) for one sex only. The most conservative strategy would be to direct management strategies toward females since F_{max} for females is lower and optimal age at entry to the fishery is higher. Mean size at maturity is also higher for females (Morse, in press).

Yield per recruit estimates for each sex were employed in conjunction with a range of possible recruitment values to determine equilibrium yields under the assumption of a 1:1 sex ratio and an age at recruitment of 2 years. Morse (in press) noted an overall 1:1 sex ratio for summer flounder collected in the Middle Atlantic region. Additional calculations were performed assuming that current levels of F are on the order of 0.80 (based on estimated $Z = 1.0$ and $M = 0.2$); projected yields under management strategies directed at females with target F levels of F_{max} (0.19) and $F_{0.1}$ (0.16) were considered in this analyses.

The relative advantage of reducing fishing mortality rates from current levels to the F_{max} assuming $t_c = 2$ years is clearly indicated (Figure 15); for example, at a recruitment level of 40×10^6 fish, estimated yield would increase from 12,000 mt at $F = 0.8$ to 17,000 mt at $F = 0.19$.

Chang and Pacheco (1975) provided stock size estimates for summer flounder in the Middle Atlantic Bight based on virtual population analysis. Geometric mean stock size for age 1 summer flounder during 1967-1972 was 57×10^6 fish. Some caution must be employed in evaluating this estimate since annual recreational catches, which were based on interpolation of the 1965 and 1970 national recreational fishing surveys, may have been inflated. In addition, age-composition of the catch was available only for samples collected in Delaware Bay during 1966-1968. Stock size estimates derived by Chang and Pacheco (1975) if qualitatively adjusted for possible over-estimation of recreational catch indicate probable average recruitment of $40\text{-}45 \times 10^6$ fish at age 2. Provisional estimates of maximum equilibrium yield would therefore range from approximately 17,000 - 20,000 mt (Figure 15). Chang and Pacheco (1975) calculated a maximum sustainable yield of 20,000 mt.

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Table 1. U.S.A. commercial summer flounder landings (MT) in NAFO[1] (Northwest Atlantic Fisheries Organization) Subarea 5 and 6 and total landings by USSR and foreign vessels 1963-1979.

	5Y	5Z	5ZE	5ZW	5NK	Subarea 5 Total	6A	6B	6C	6NK	Area 6 Total	USSR	Other Countries	Total USA
1963	5	1009	--	--	0	1014	--	--	--	3858	3858	0	0	4872
1964	2	620	--	--	0	622	--	--	--	3768	3768	0	0	4390
1965	0	621	--	--	0	621	--	--	--	4386	4386	22	0	5007
1966	38	286	--	--	0	324	--	--	--	4237	4237	31	0	4561
1967	36	453	--	--	0	489	--	--	--	3401	3401	72	0	3890
1968	34	--	40	141		215	31	4	0	2668	2703	35	0	2918
1969	18	--	23	81	0	122	22	0	0	1525	1547	294	0	1669
1970	21	--	10	105	0	136	23	0	0	2448	2471	36	0	2607
1971	12	--	28	122	0	162	52	0	0	2256	2308	904	0	2470
1972	10	--	9	162	0	181	50	0	0	3057	3107	393	0	3288
1973	0	--	40	334	0	374	61	3	0	3922	3986	22	0	4360
1974	22	--	285	1381	0	1688	2155	1737	724	747	5363	0	0	7051
1975	17	--	279	1718	57	2071	2474	2629	449	0	5552	0	26	7623
1976	23	--	648	3054	57	3782	3423	3073	479	0	6975	0	9	10,757
1977	25	--	816	1117	82	2040	2600	3577	667	0	6844	0	52	8884
1978	7	--	710	1231	79	2027	1889	3534	1004	0	6427	0	12	8454
1979*	5	--	793	904	94	1796	1719	5566	5451	0	12736		11	14,532
1980*	4	--	305	404	7	720	1519	4470	4825	0	10814			11,534

[1]Formerly ICNAF (International Commission for Northwest Atlantic Fisheries).

*Provisional landings.

Table 2. Estimated recreational catch of summer flounder based on national and regional recreational fishing surveys, corresponding commercial catch, and percentage of total comprised of recreational catch.

Survey Year	Recreational Catch (mt)	Commercial Catch (mt)	Percent Recreational
1965	13,432	4,465	77.05
1970	8,778	2,585	77.25
1974	15,830	6,738	70.14
1979	8,626	14,500	37.30

Table 3. Stratified mean weight (kg) per tow of summer flounder from NMFS, NEFC spring bottom trawl surveys in the Middle Atlantic (strata 61-76), southern New England (strata 1-12) and on Georges Bank (strata 13-25), Standard deviation of the mean (S.D.) and coefficient of variation (C.V.) are provided as indices of variability. Catches adjusted to No. 36 trawl (1973-1980).

	Georges Bank			S. New England			Mid-Atlantic		
Year	$\overline{X}$	S.D.	C.V.	$\overline{X}$	S.D.	C.V.	$\overline{X}$	S.D.	C.V.
1968	0	--	--	0.08	0.042	0.520	0.26	0.125	0.481
1969	0	--	--	0	--	--	0.35	0.135	0.386
1970	0	--	--	0	--	--	0.19	0.084	0.441
1971	0	--	--	0.31	0.155	0.499	0.25	0.117	0.469
1972	0	--	--	0.02	0.020	1.016	0.43	0.112	0.261
1973	*	--	--	0.41	0.132	0.322	0.40	0.114	0.285
1974	0.06	0.057	0.951	0.97	0.332	0.342	0.95	0.326	0.343
1975	0.03	0.021	0.701	1.79	0.514	0.287	0.45	0.075	0.166
1976	0.02	0.012	0.605	1.89	0.103	0.054	1.09	0.245	0.225
1977	0.05	0.033	0.663	1.09	0.280	0.257	1.62	0.314	0.194
1978	0.22	0.101	0.460	0.79	0.248	0.314	1.45	0.305	0.211
1979	0	--	--	0.20	0.106	0.530	0.34	0.082	0.242
1980	0.06	0.041	0.683	0.45	0.123	0.273	0.77	0.116	0.150

*<0.01

Table 4. Stratified mean number per tow of summer flounder from NMFS, NEFC spring bottom trawl surveys in the Middle Atlantic (strata 61-76), southern New England (strata 1-12) and on Georges Bank (strata 13-25), standard deviation of the mean (S.D.) and coefficient of variation (C.V.) are provided as indices of variability. Catches are adjusted to No. 36 trawl (1973-1980).

	Georges Bank			S. New England			Mid-Atlantic		
Year	$\overline{X}$	S.D.	C.V.	$\overline{X}$	S.D.	C.V.	$\overline{X}$	S.D.	C.V.
1968	0	--	--	0.06	0.032	0.531	0.27	0.117	0.433
1969	0	--	--	0	--	--	0.42	0.141	0.335
1970	0	--	--	0	--	--	0.20	0.069	0.345
1971	0	--	--	0.13	0.049	0.377	0.33	0.123	0.372
1972	0	--	--	0.01	0.015	1.493	1.02	0.294	0.288
1973	*	--	--	0.32	0.072	0.225	0.97	0.252	0.260
1974	0.09	0.076	0.846	1.00	0.345	0.345	1.25	0.399	0.320
1975	0.03	0.017	0.573	1.90	0.597	0.315	1.18	0.108	0.092
1976	0.03	0.019	0.639	2.38	0.138	0.058	2.22	0.394	0.177
1977	0.06	0.039	0.648	1.62	0.464	0.287	3.13	0.581	0.185
1978	0.27	0.115	0.428	0.96	0.291	0.303	3.37	0.776	0.230
1979	0	--	--	0.13	0.056	0.433	0.56	0.148	0.264
1980	0.03	0.020	0.633	0.30	0.069	0.229	1.95	0.349	0.179

*<.01 fish/tow

Table 5. Stratified mean weight (kg) per tow of summer flounder from NMFS, NEFC autumn bottom trawl surveys in the Middle Atlantic (strata 61-76), southern New England (strata 1-12) and on Georges Bank (strata 13-25). Standard deviation of the mean (S.D.) and coefficient of variation (C.V.) are provided as indices of variability.

	Georges Bank			S. New England			Mid-Atlantic[1]		
Year	$\overline{X}$	S.D.	C.V.	$\overline{X}$	S.D.	C.V.	$\overline{X}$	S.D.	C.V.
1963	0	--	--	0.54	0.192	0.356	--	--	--
1964	0	--	--	0.93	0.449	0.483	--	--	--
1965	0	--	--	0.06	0.041	0.683	--	--	--
1966	0	--	--	0.01	0.009	0.882	--	--	--
1967	0	--	--	0.10	0.099	0.986	2.01	0.589	0.239
1968	0	--	--	0.16	0.159	0.993	1.51	0.422	0.279
1969	0	--	--	0.25	0.120	0.481	0.76	0.301	0.396
1970	0	--	--	0.15	0.109	0.727	0.04	0.030	0.744
1971	0	--	--	0.04	0.038	0.941	0.41	0.147	0.359
1972	0	--	--	0.25	0.082	0.329	0.15	0.051	0.343
1973	0.01	0.012	1.200	0.61	0.333	0.546	0.33	0.099	0.301
1974	0.04	0.027	0.663	1.93	0.450	0.233	0.85	0.362	0.426
1975	0.20	0.136	0.678	1.15	0.321	0.279	2.92	0.567	0.194
1976	0.16	0.079	0.491	0.75	0.175	0.233	0.55	0.170	0.309
1977	0.34	0.141	0.414	1.59	0.444	0.279	1.07	0.604	0.565
1978	0.18	0.054	0.297	0.52	0.168	0.322	0.05	0.023	0.461
1979	0.12	0.053	0.438	0.82	0.285	0.348	0.61	0.256	0.420
1980	0.29	0.157	0.542	0.60	0.260	0.433	0.29	0.100	0.344

[1]Mid-Atlantic not sampled prior to 1967.

Table 6. Stratified mean number per tow of summer flounder from NMFS, NEFC autumn bottom trawl surveys in the Middle Atlantic (strata 61-76), southern New England (strata 1-12) and on Georges Bank (strata 13-25). Standard deviation of the mean (S.D.) and coefficient of variation (C.V.) are provided as indices of variability.

	Georges Bank			S. New England			Mid-Atlantic[1]		
Year	$\bar{X}$	S.D.	C.V.	$\bar{X}$	S.D.	C.V.	$\bar{X}$	S.D.	C.V.
1963	0	--	--	0.60	0.217	0.361	--	--	--
1964	0	--	--	0.41	0.182	0.444	--	--	--
1965	0	--	--	0.06	0.046	0.768	--	--	--
1966	0	--	--	0.02	0.019	0.973	--	--	--
1967	0	--	--	0.02	0.017	0.836	2.28	0.619	0.272
1968	0	--	--	0.04	0.037	0.922	1.82	0.460	0.253
1969	0	--	--	0.10	0.052	0.520	0.92	0.326	0.355
1970	0	--	--	0.07	0.035	0.483	0.17	0.116	0.684
1971	0	--	--	0.02	0.021	1.037	0.68	0.212	0.311
1972	0	--	--	0.21	0.066	0.315	0.42	0.131	0.313
1973	0.01	0.006	0.637	0.44	0.202	0.460	0.96	0.269	0.280
1974	0.03	0.023	0.763	1.26	0.297	0.236	1.37	0.484	0.353
1975	0.15	0.094	0.628	1.02	0.319	0.313	4.00	0.819	0.205
1976	0.11	0.045	0.409	0.68	0.168	0.247	1.12	0.290	0.259
1977	0.35	0.150	0.428	1.33	0.365	0.274	2.11	0.977	0.463
1978	0.12	0.038	0.313	0.34	0.109	0.321	0.13	0.066	0.510
1979	0.07	0.028	0.393	0.43	0.157	0.364	1.48	0.651	0.440
1980	0.12	0.075	0.621	0.33	0.119	0.362	1.20	0.433	0.361

[1]Mid-Atlantic not sampled prior to 1967.

Table 7. Parameters of the von Bertalanffy growth equation derived for summer flounder in the Middle Atlantic Bight. Asymptotic standard errors for each parameter provided in parentheses. Rao's homogeneity X^2 test was used to test for sex related differences in the parameters L_∞ and k

Parameter	Male	Female	X^2
L_∞	72.72 (6.36)	90.61 (6.14)	47.55**
k	0.17899 (.030007)	0.16406 (.02101)	0.169
t_o	-0.2587 (.16015)	0.0475 (.12719)	

Table 8. Estimates of annual survival rate and instantaneous fishing mortality rate for summer flounder based on tag-recapture experiments using the maximum likelihood method of Paulik (1963).

Area	Release Dates	Tag Type	Number Released	Number Recovered	$\hat{S}$	$\hat{F}$	Source
Nantucket Sound	Sept. 6-8, 21, 1962	Petersen Disc	600	245	0.307	0.482	Lux 1980
Block Island Sound	Sept. 6-8, 1962	Petersen Disc	406	203	0.289	0.622	Lux 1980
New Jersey	Sept. 23-Oct. 19, 1980	Atkins Tag	692	96	0.174	0.244	Murawski 1970
New Jersey	July 31-Aug. 10, 1961	Atkins Tag	613	133	0.102	0.496	Murawski 1970
New Jersey	July 18 - Aug. 31, 1961	Petersen Disc	2,767	949	0.314	0.397	Murawski 1970
New Jersey	June 20 - Aug. 29, 1966	Petersen Disc	1,392	420	0.147	0.580	Murawski 1970
New Jersey	June 12 - Aug. 22, 1966	Petersen Disc	1,205	296	0.192	0.407	Murawski 1970
North Carolina	Nov. 8, 1973-Dec. 19, 1974	Peterson Disk	7,040*	178	0.343	0.107	Gillikin, personal communication
		>30 cm TL ONLY	2,300*	133	0.396	0.240	

*Adjusted total (see text)

Table 9. Estimates of annual survival rate and instantaneous rate of total mortality based on catch curve analysis of survey and commercial age-length data. Standard errors of estimates in parentheses.

Sample Year	Survey						Commercial			
	Female				Male		Sexes Combined			
	S		Z		S		Z	S		Z	
1976	0.26	(.028)	1.35	(.109)	0.20	(.027)	1.60	(.138)	0.33	(.002)	1.10	(.005)
1977	0.35	(.041)	1.05	(.116)	0.41	(.046)	0.87	(.110)	0.10	(.006)	2.26	(.065)
1978	0.51	(.025)	0.68	(.050)	0.04	(.037)	2.85	(.037)	0.40	(.009)	0.91	(.024)
1979	0.51	(.031)	0.67	(.061)	0.41	(.035)	0.89	(.034)	0.13	(.006)	2.07	(.049)
TOTAL	0.40	(0.21)	0.93	(.053)	0.33	(.018)	1.11	(.055)				

Table 10. Effects on yield per recruit (kg) of varying age at entry to the fishery by adjusting minimum legal size limits at two levels of fishing mortality (0.50, 0.75) for male and female summer flounder at an assumed natural mortality rate of M = 0.2.

Minimum Length (cm)	Male		Female	
	0.50	0.75	0.50	0.75
25.4 (10")	0.31	0.27	0.44	0.36
27.9 (11")	0.33	0.30	0.48	0.40
30.5 (12")	0.36	0.33	0.51	0.44
33.0 (13")	0.38	0.36	0.55	0.49
35.6 (14")	0.40	0.39	0.59	0.53
38.1 (15")	0.42	0.42	0.63	0.58

Table 11. Effect of varying instantaneous natural mortality rates (M) on yield per recruit (kg) and F_{max} (in parentheses) for male (M) and female (F) summer flounder.

	NATURAL MORTALITY					
	0.1		0.2		0.3	
	Male	Female	Male	Female	Male	Female
$t_c = 2$	0.485 (.26)	1.135 (.13)	0.310 (.32)	0.548 (.19)	0.212 (.40)	0.321 (.28)
$t_c = 3$	0.585 (.35)	1.276 (.16)	0.372 (.45)	0.632 (.25)	0.251 (.62)	0.379 (.42)
$t_c = 4$	0.690 (0.49)	1.424 (.20)	0.427 (0.66)	0.713 (.35)	0.279 (1.00)	0.429 (.69)

Table 12. Effect of varying growth parameters L_∞ and k by ± 10% on maximum yield per recruit (kg) and F_{max} (in parentheses) for female summer flounder.

	L_∞	k	L_∞^{+10}	k^{+10}	L_∞^{-10}	k^{-10}
L_∞		0.55 (0.19)		0.65 (0.20)		0.45 (0.18)
k			0.75 (0.19)		0.39 (0.19)	
L_∞^{+10}				0.88 (0.20)		0.62 0.18)
k^{+10}					0.48 (0.21)	
L_∞^{-10}						0.32 (0.18)

Table 13. Effects of varying growth parameters L and k by ± 10% on maximum yield per recruit (kg) and F_{max} (in parentheses) for male summer flounder

L_∞	k	L^{+10}	k^{+10}	L_∞^{-10}	k^{-10}
L_∞	0.31 (0.32)		0.37 (0.33)		0.25 (0.31)
k		0.42 (0.32)		0.22 (0.32)	
L_∞^{+10}			0.498 (0.33)		0.34 (0.31)
k^{+10}				0.27 (0.33)	
L_∞^{-10}					0.18 (0.32)

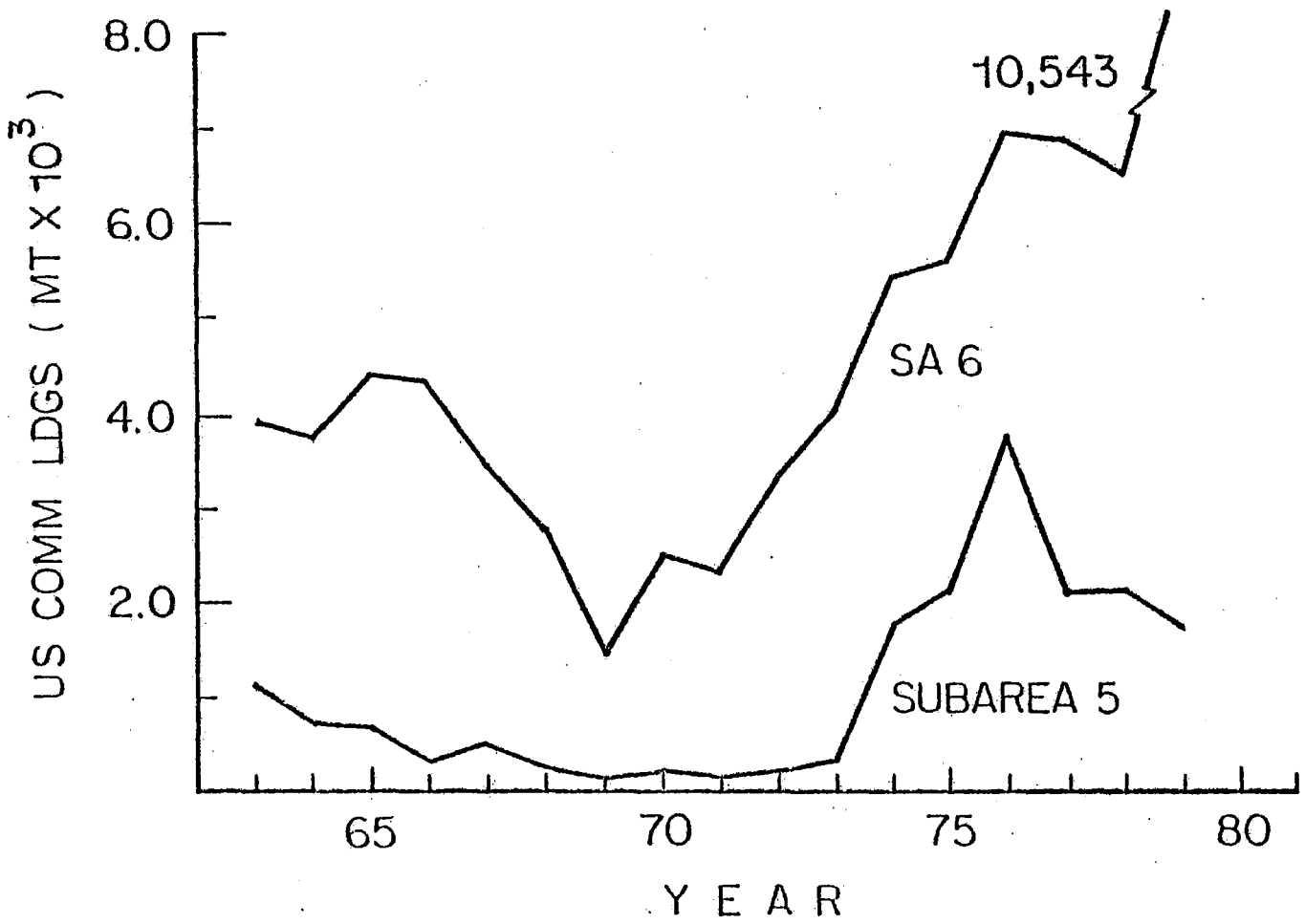

Figure 1. U.S. commercial landings (thousands of metric tons) for summer flounder in ICNAF/NAFO Subarea 5 and Statistical Area 6.

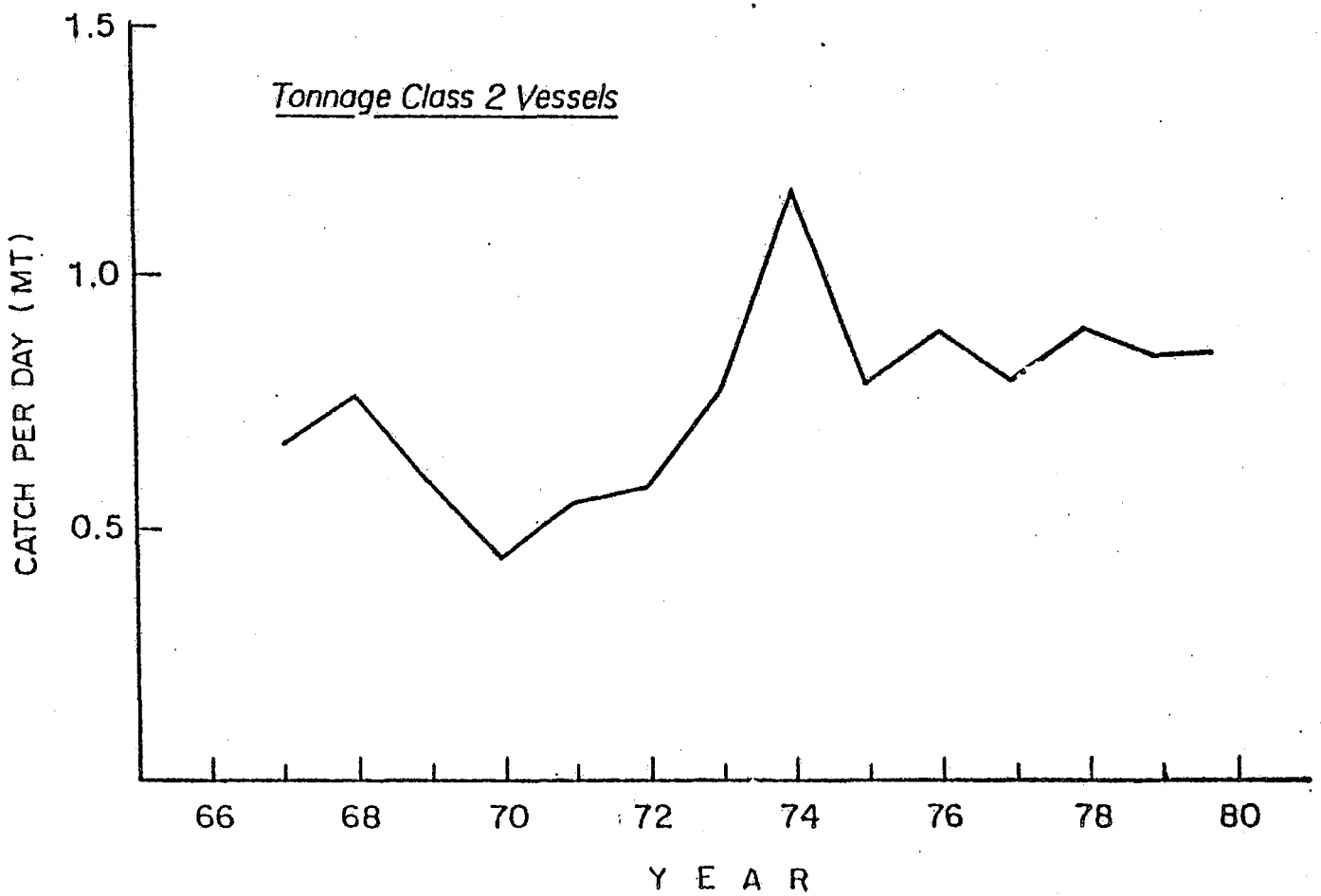

Figure 2. Catch per day fished for tonnage class 2 vessels (50 GRT)

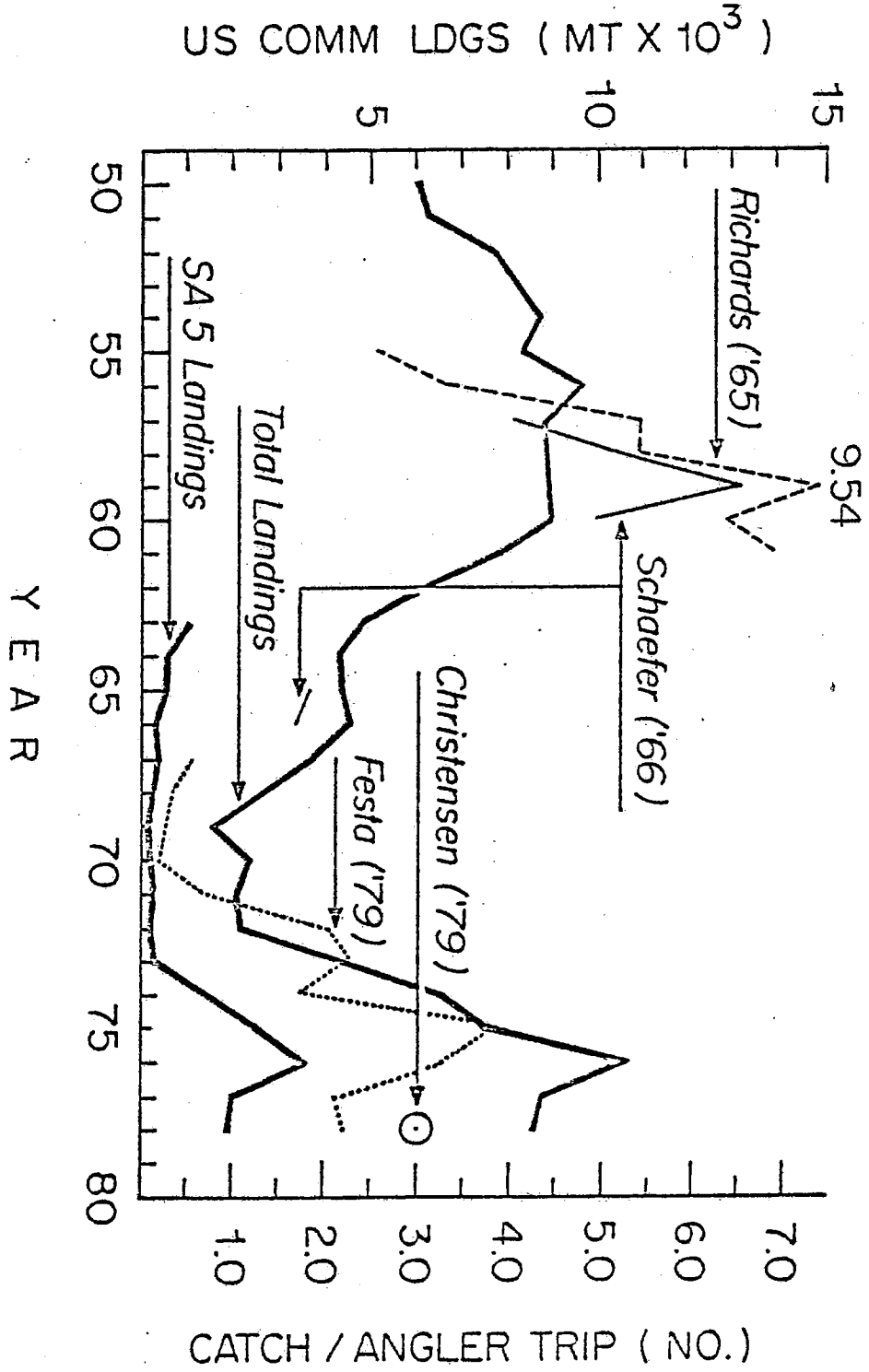

Figure 5. Recreational catch per angler trip of summer flounder for localized creel census surveys conducted in the Middle Atlantic Bight. Total U.S. commercial landings (thousands of metric tons) provided for reference.

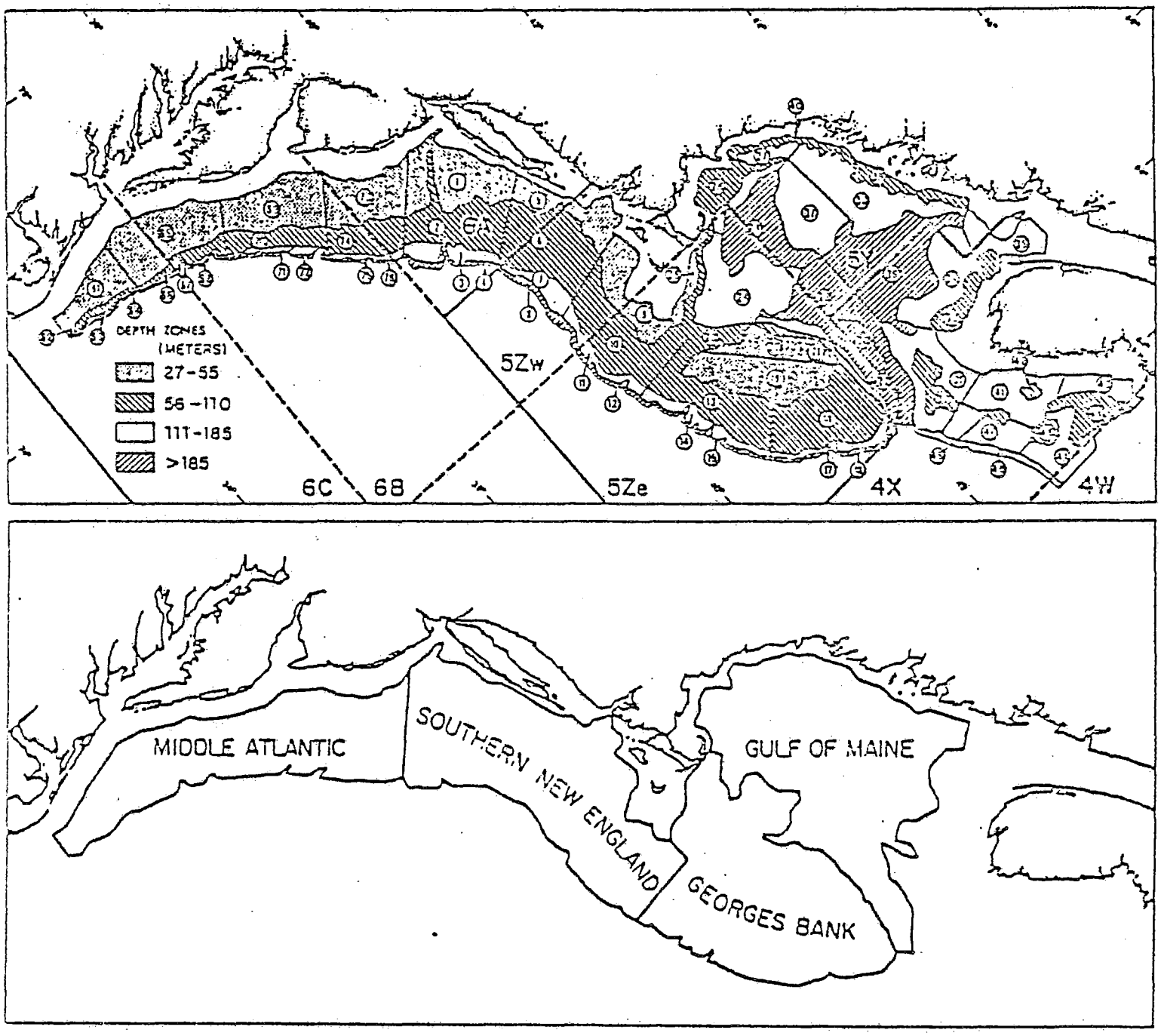

Figure 4. Sampling strata and strata groupings used in NMFS, NEFC research bottom trawl surveys.

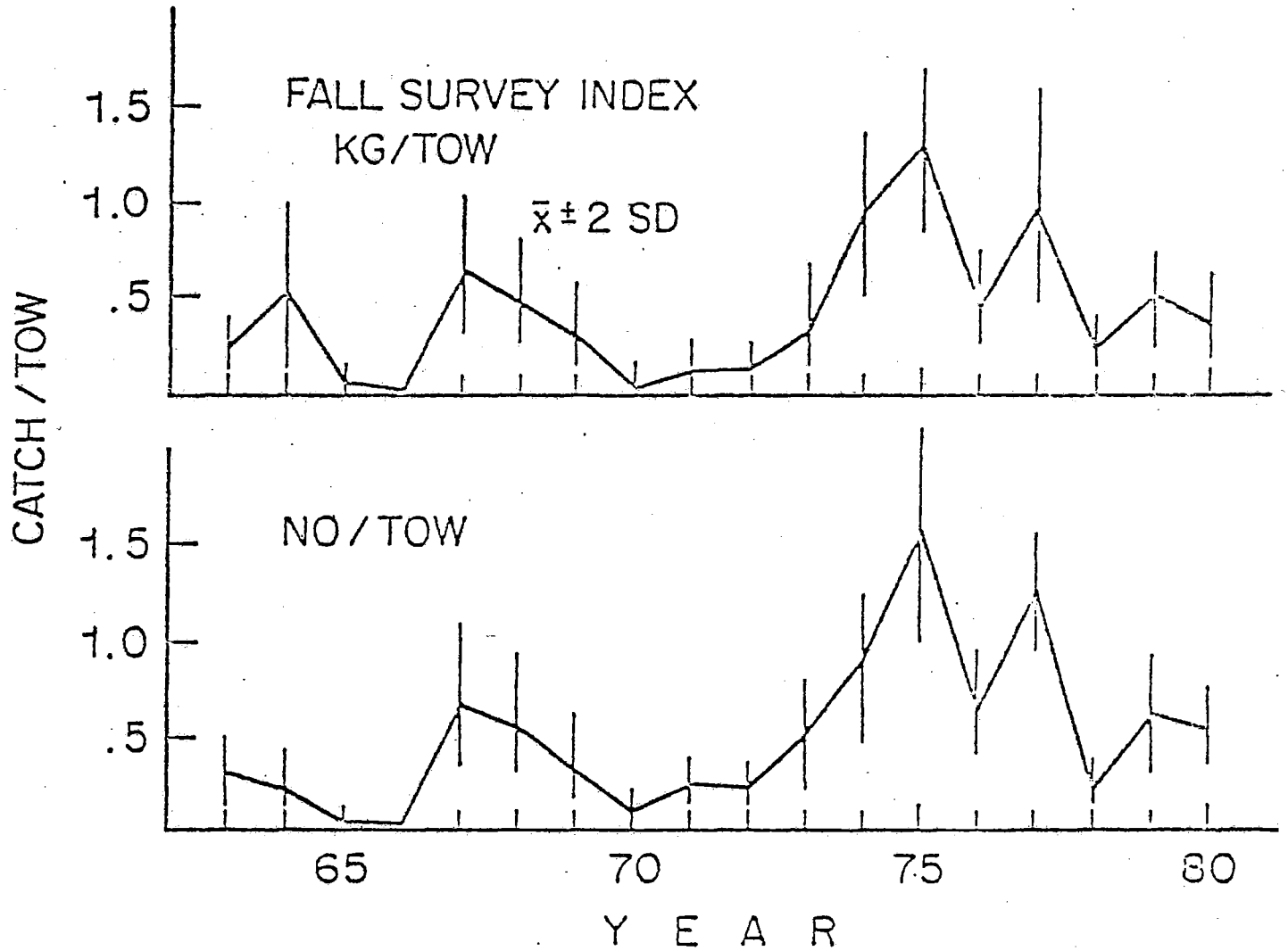

Figure 5. Stratified mean catch per tow of summer flounder for NMFS, NEFC autumn bottom trawl surveys in weight (upper) and numbers (lower

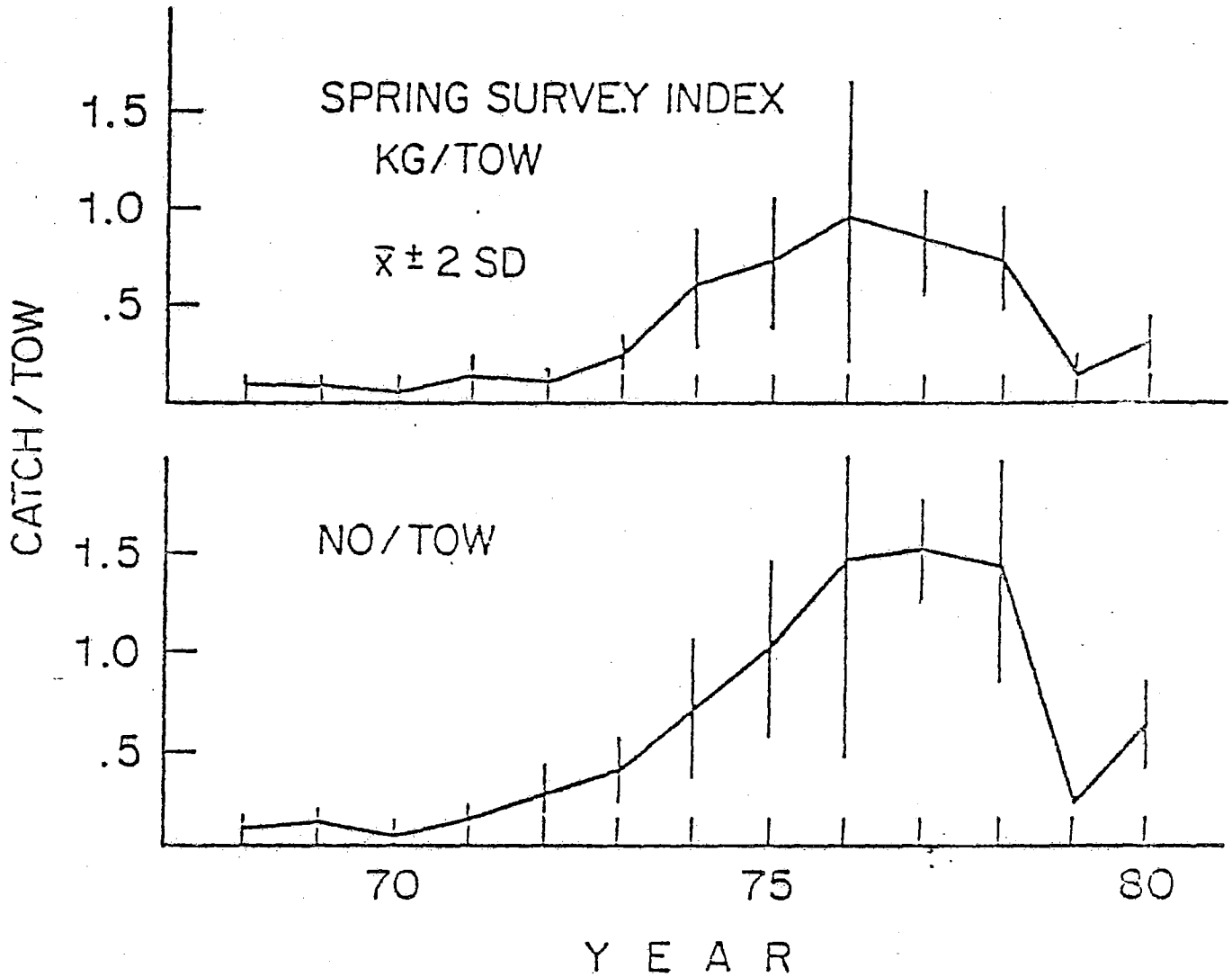

Figure 6. Stratified mean catch per tow of summer flounder for NMFS, NEFC spring bottom trawl surveys in weight (upper) and numbers (lower.

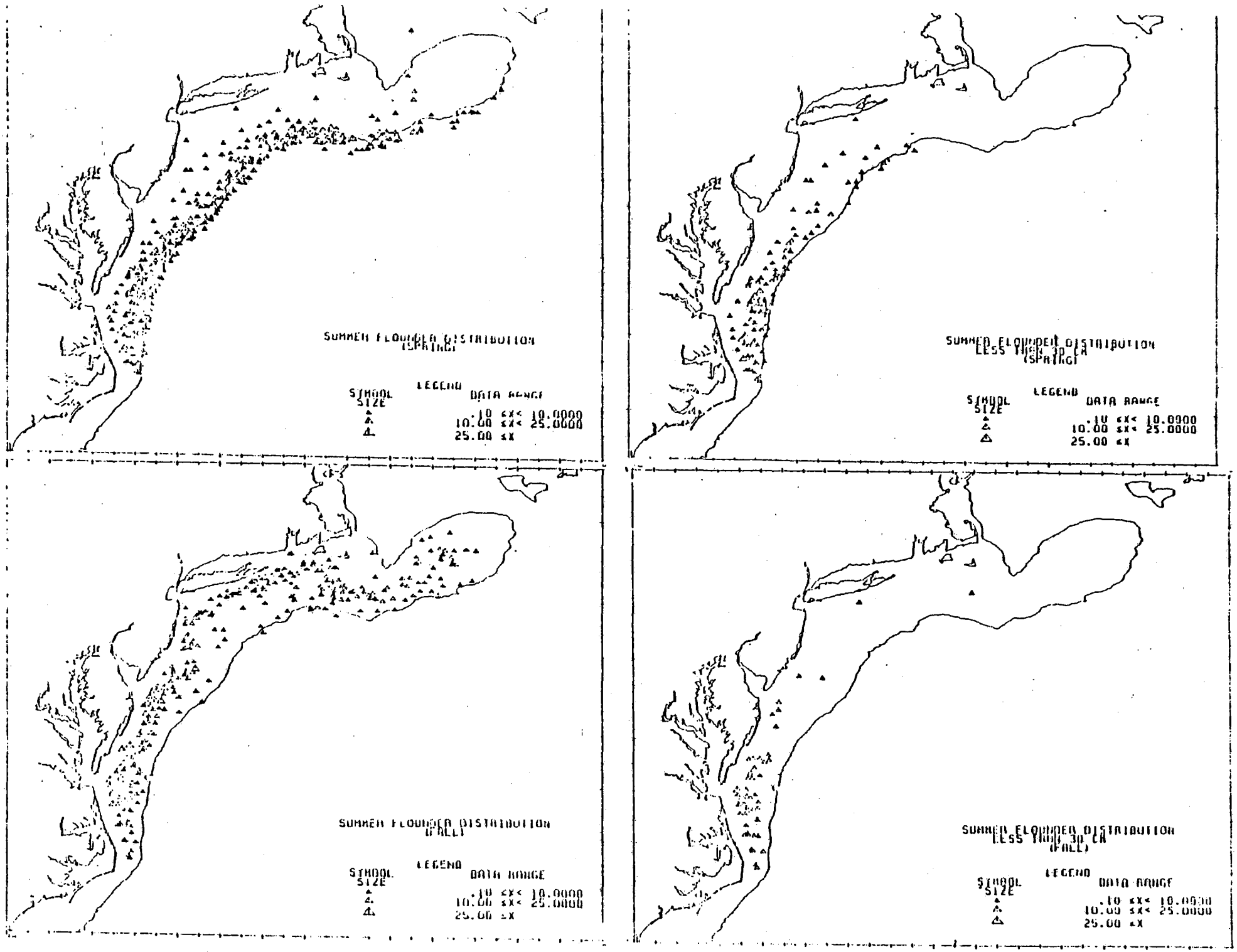

Figure 7. Distribution of summer flounder in Middle Atlantic Bight based on NMFS,NEFC groundfish trawl surveys in spring and autumn.

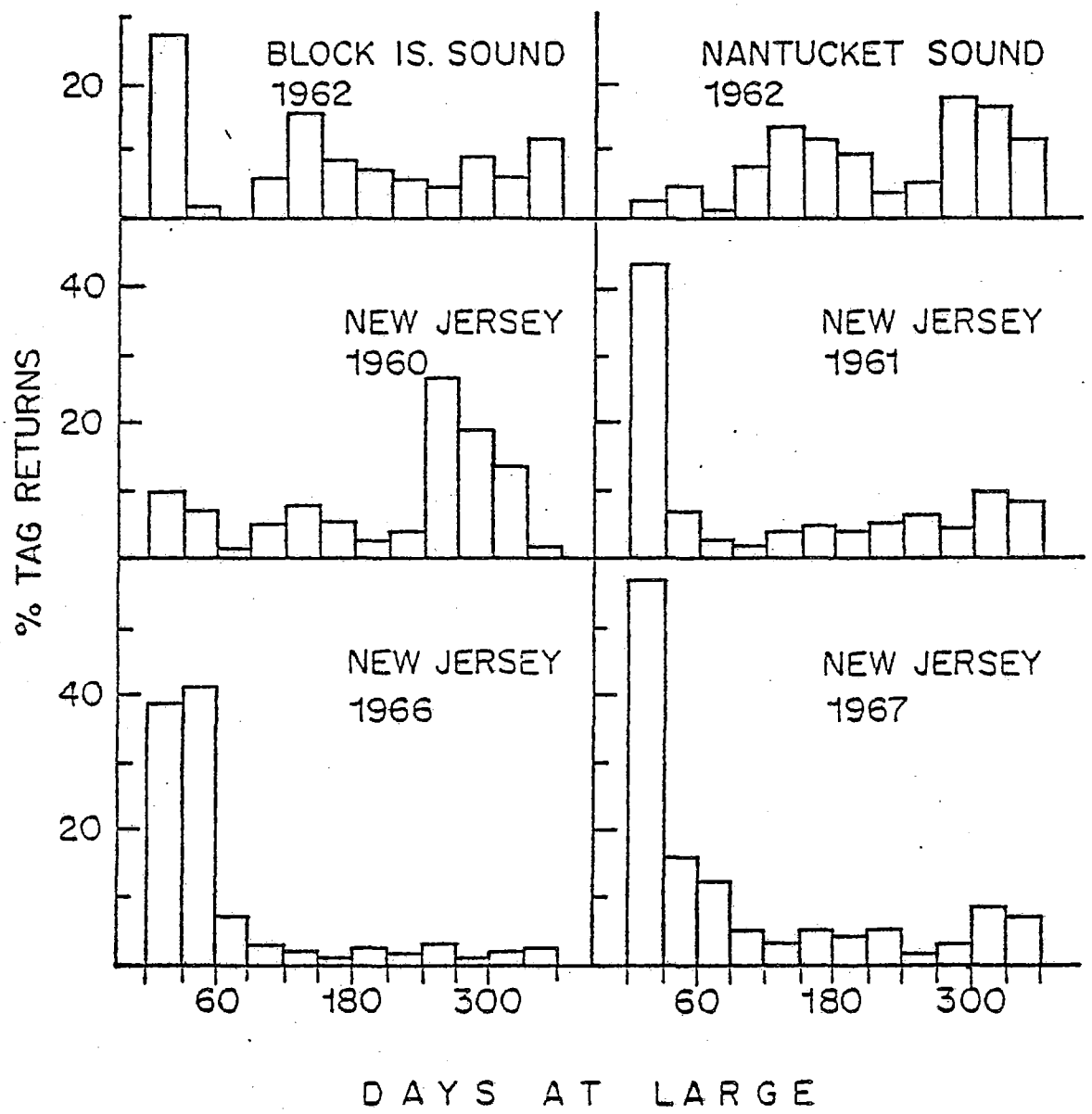

Figure 8. Distribution of tag returns for summer flounder as a function of time at large during the initial 360 days from release from experiments conducted off southern New England in 1962 and New Jersey during 1960, 1961, 1966, 1967.

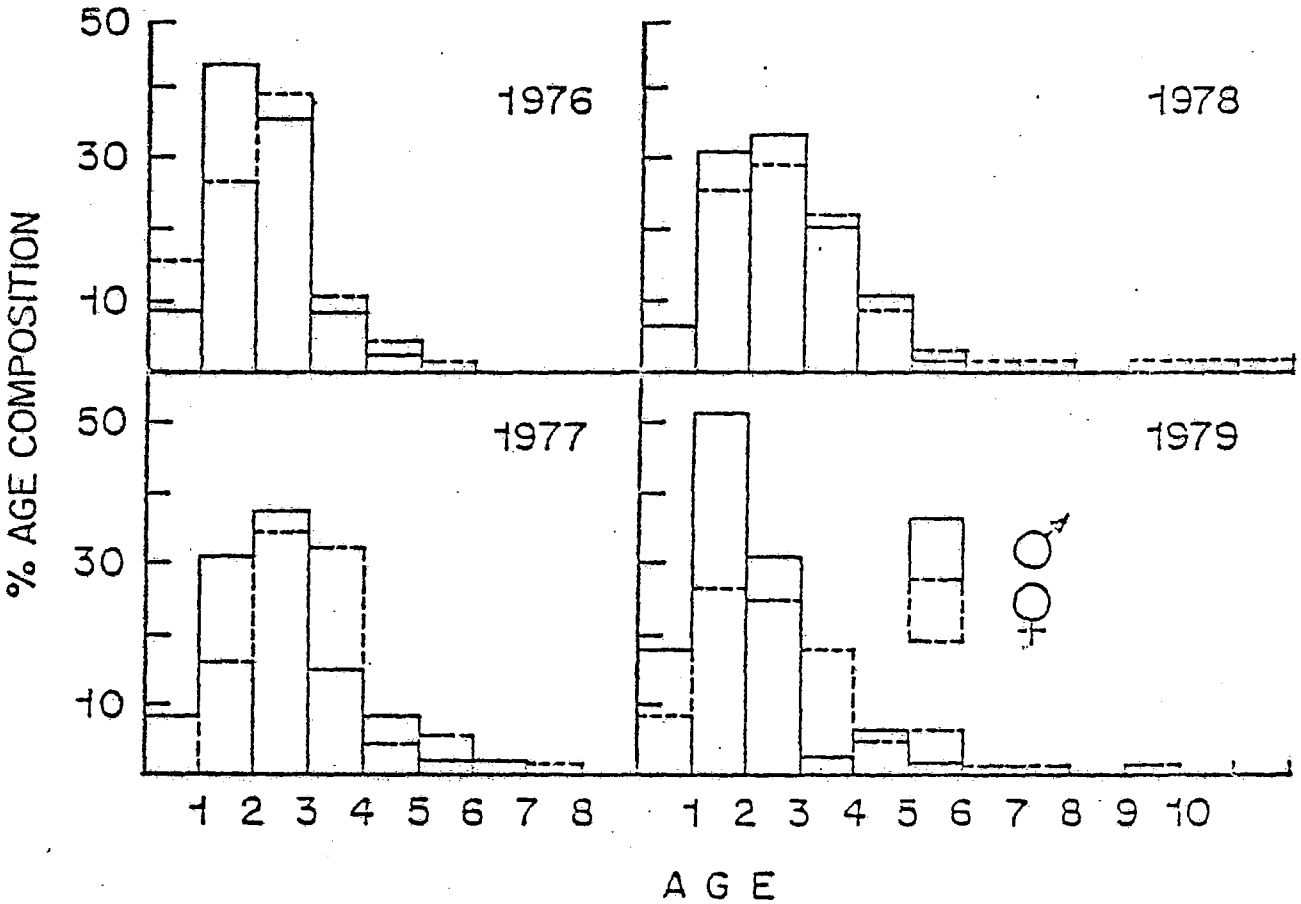

Figure 9. Percent age composition of male and female summer flounder collected during NMFS, NEFC bottom trawl surveys (1976-1979).

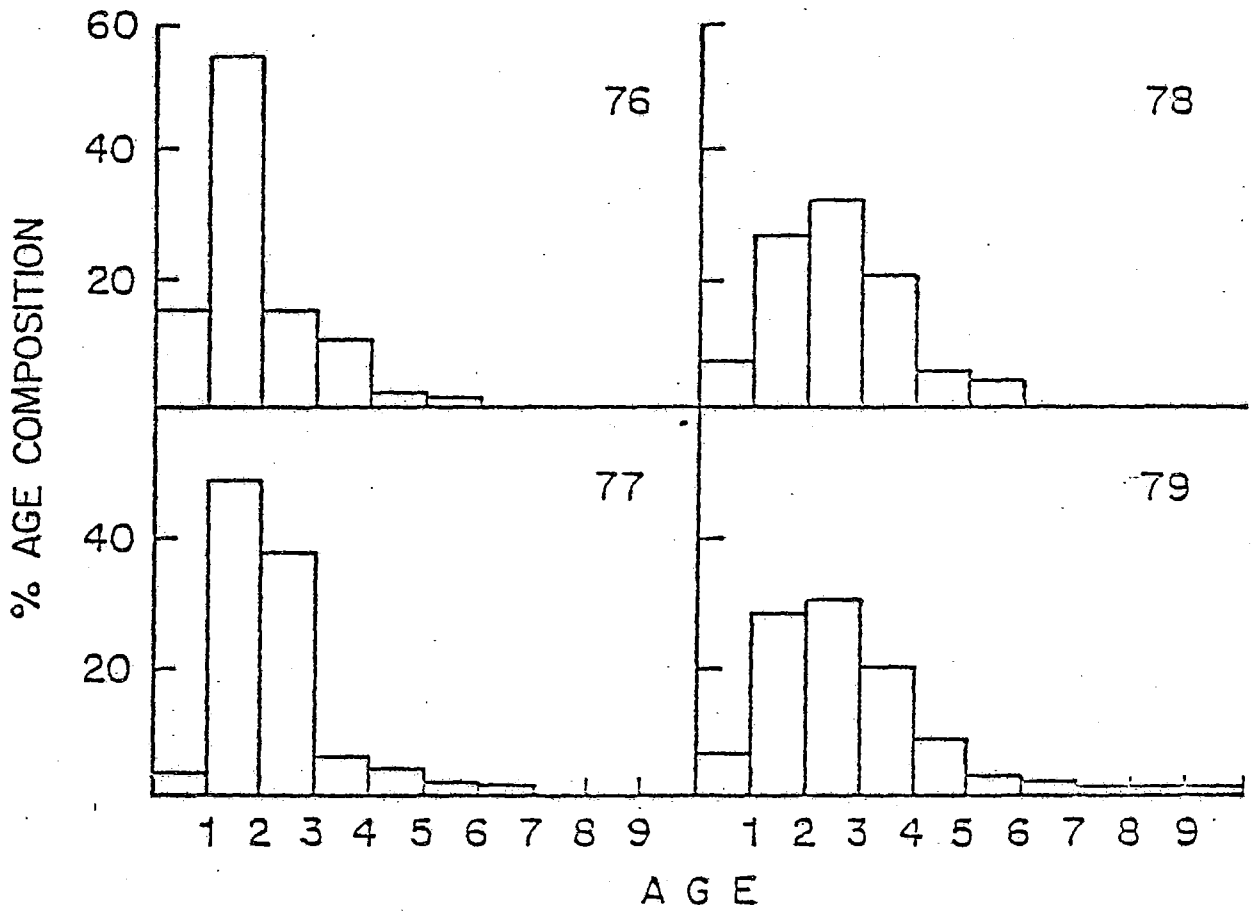

Figure 10. Percent age composition of summer flounder (sexes combined) commercial samples collected during 1976-1979.

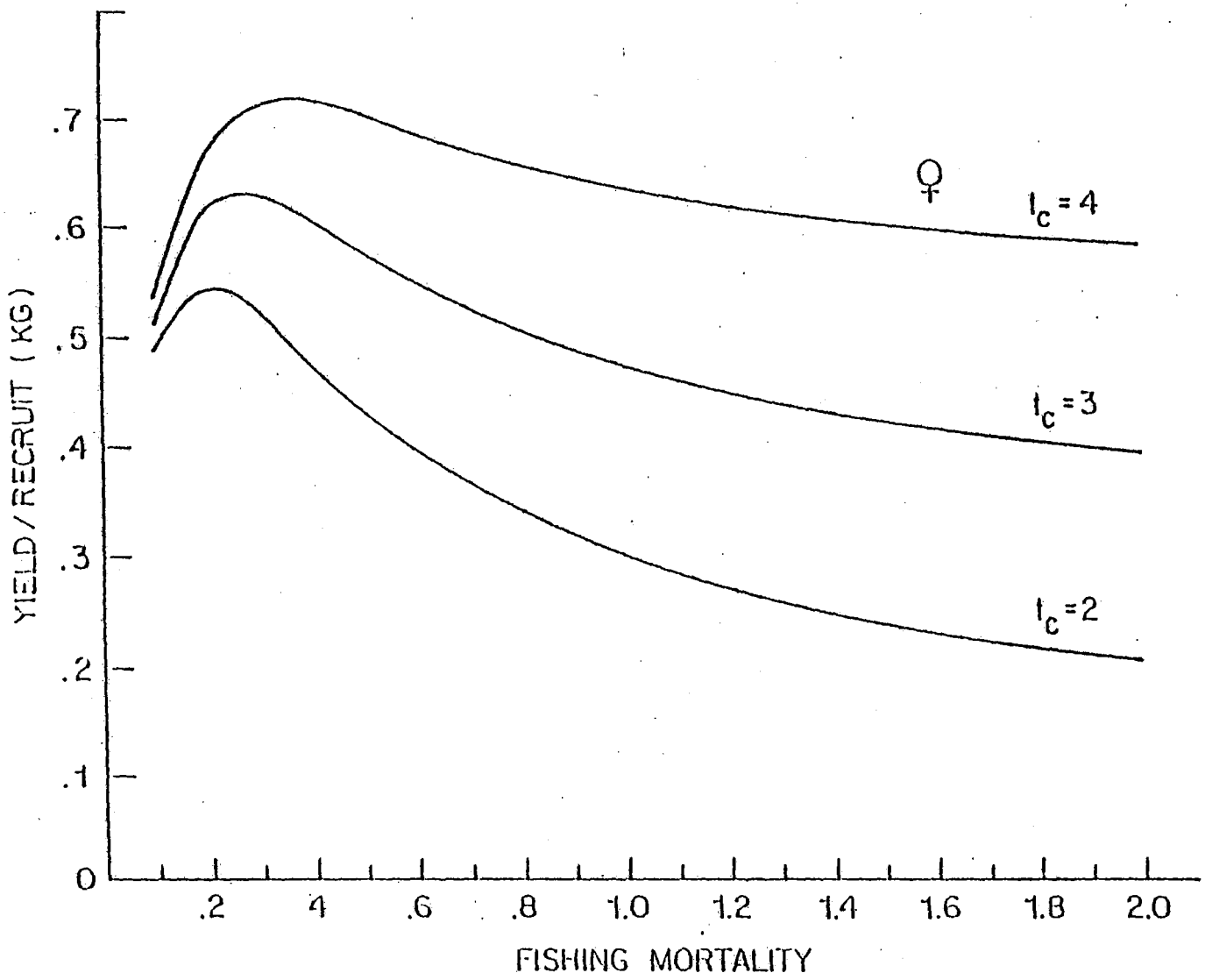

Figure 11. Yield per recruit (kg) as a function of fishing mortality for female summer flounder assuming m = 0.2.

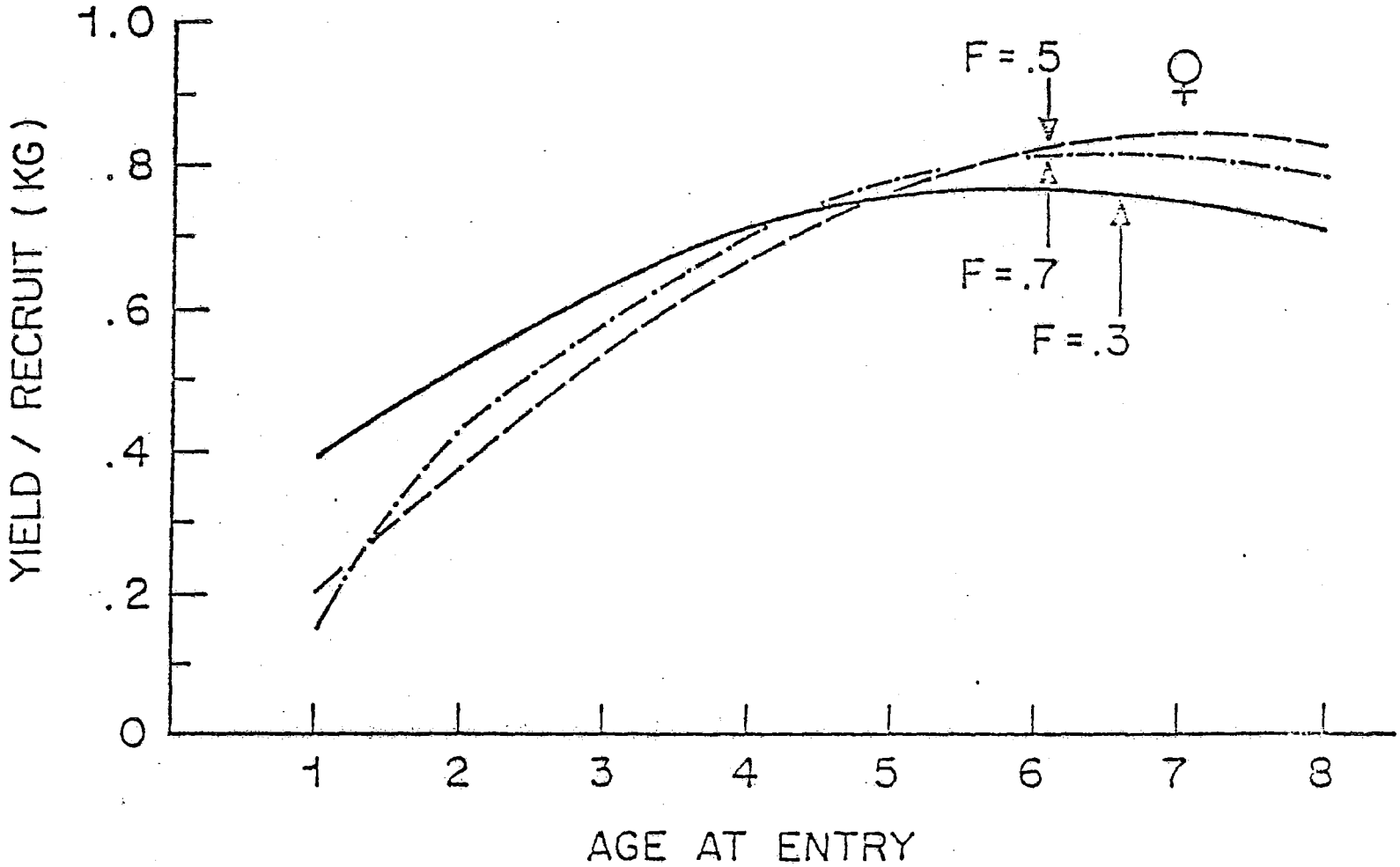

Figure 12. Yield per recruit (kg) as a function of age at entry to the fishery for female summer flounder assuming m = 0.2.

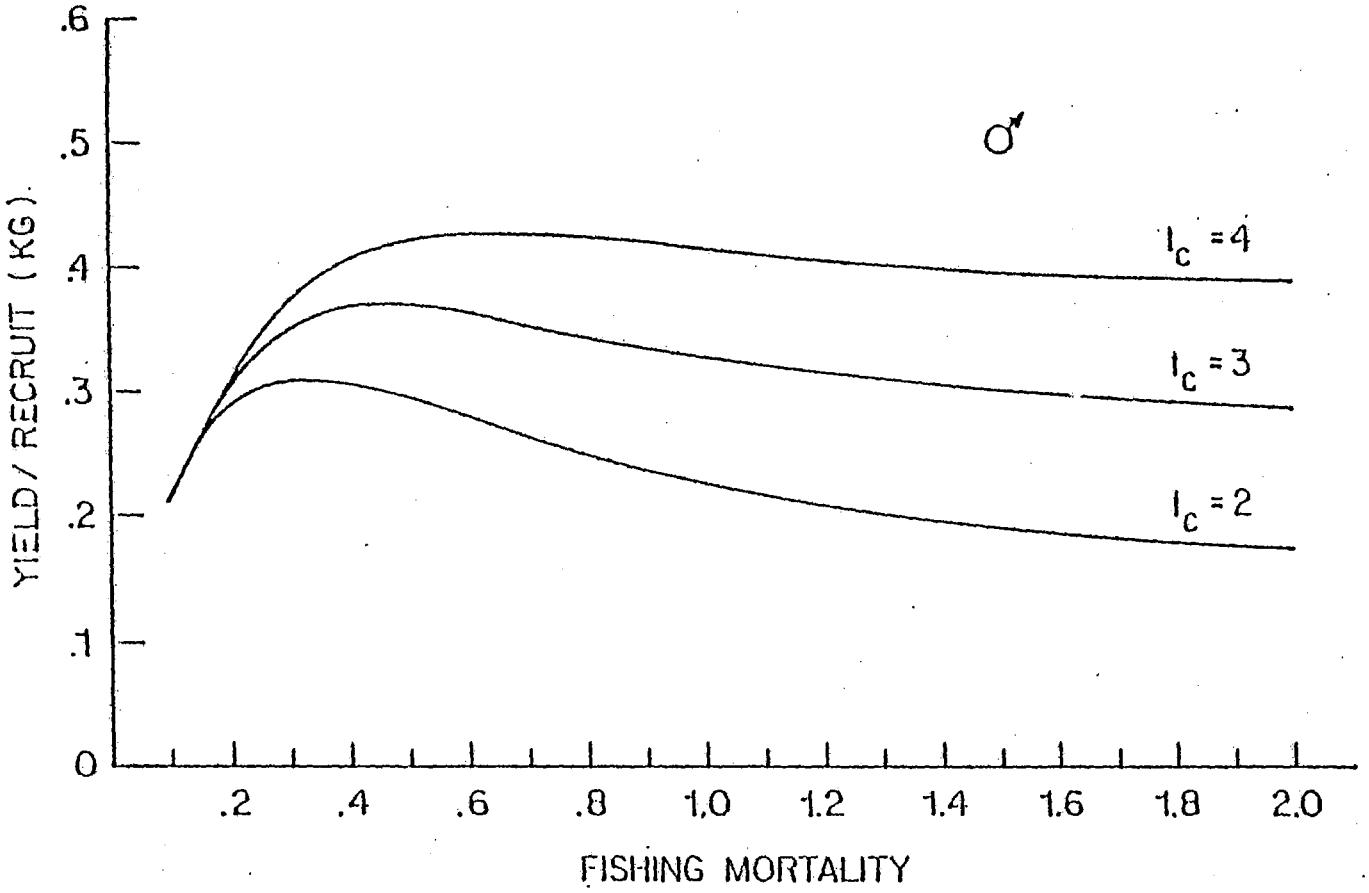

Figure 13. Yield per recruit (kg) as a function of fishing mortality for male summer flounder assuming m = 0.2.

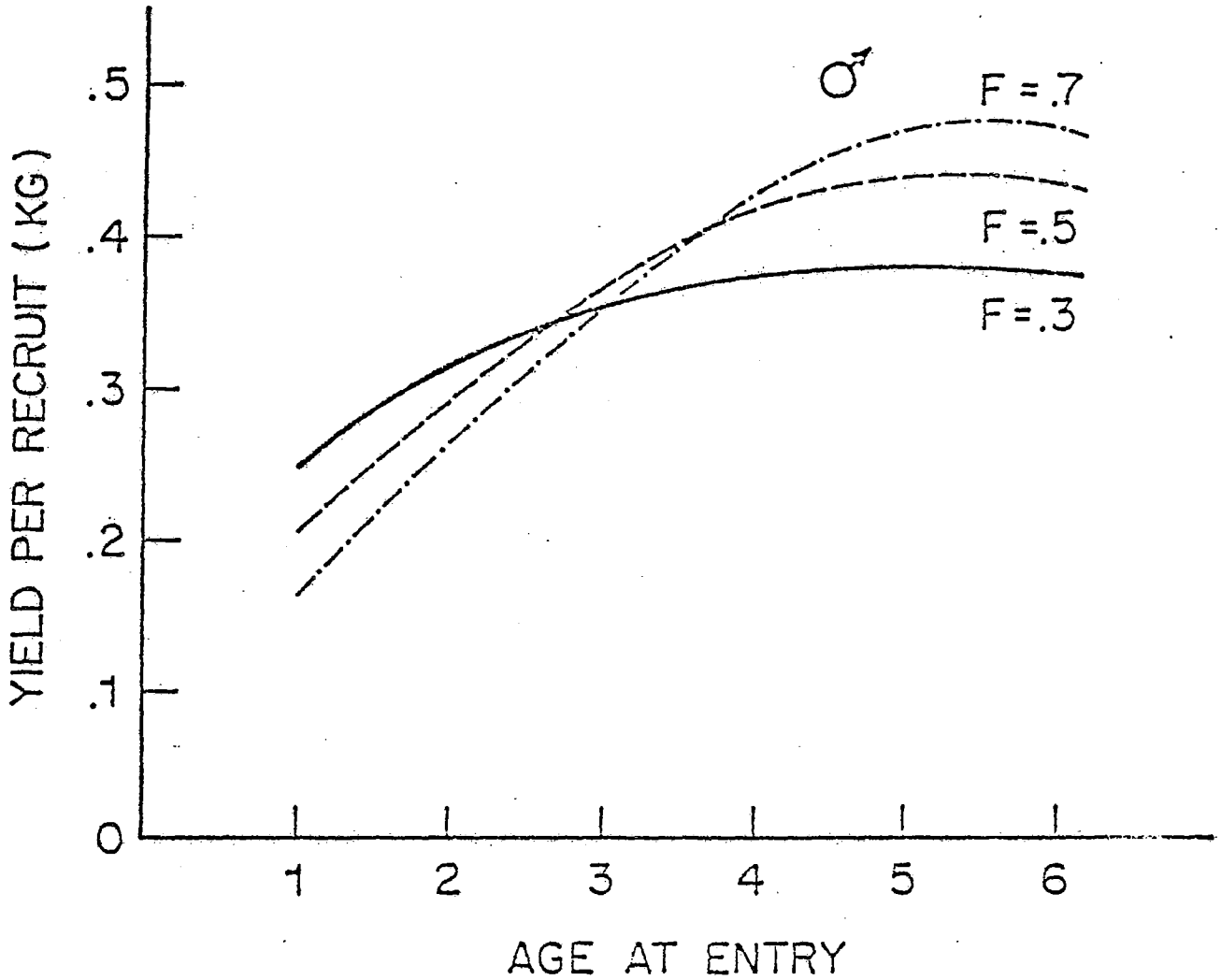

Figure 14. Yield per recruit (kg) as a function of age at entry to the fishery for male summer flounder assuming m = 0.2.

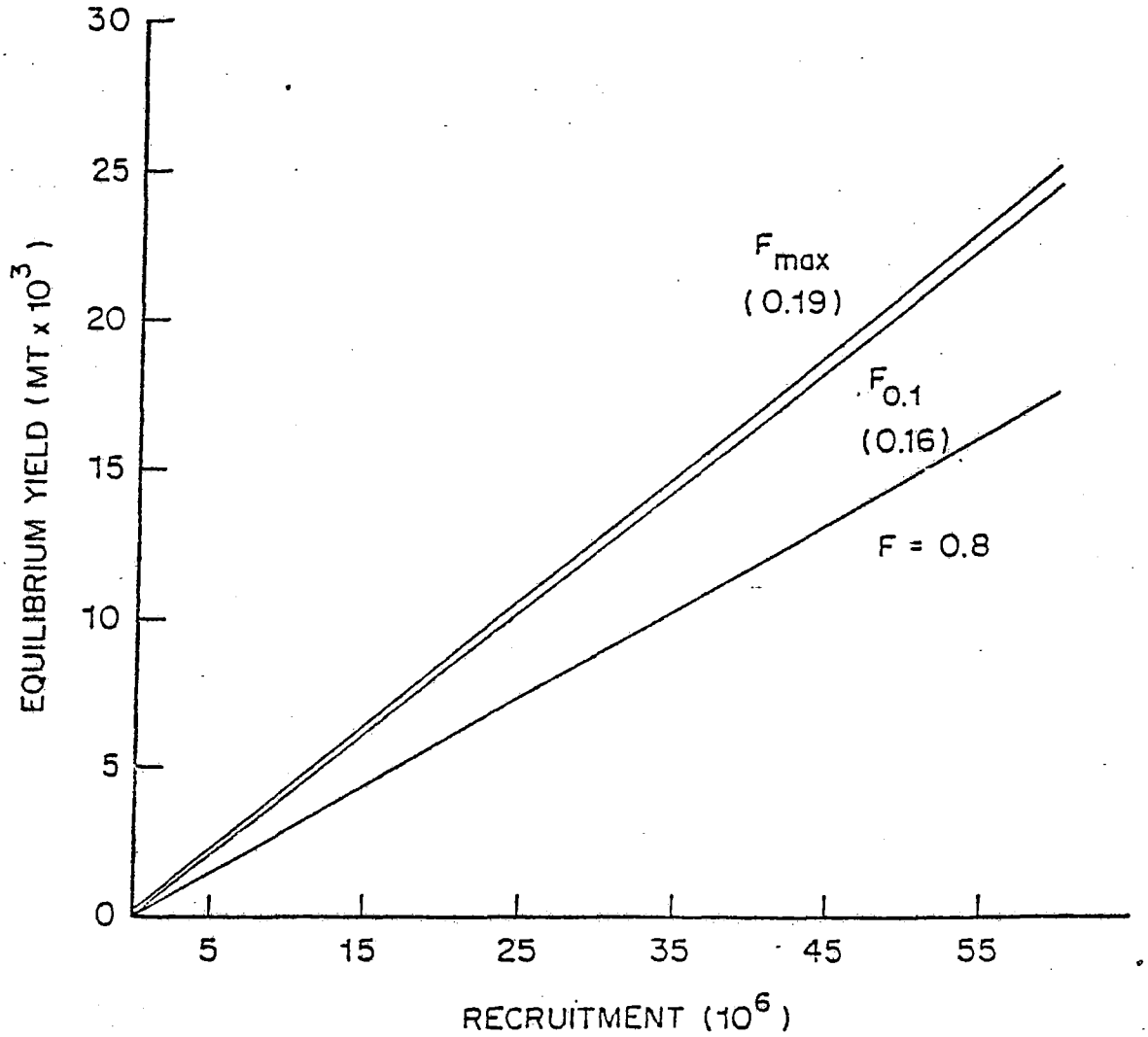

Figure 15. Equilibrium yield (MT) as a function of recruitment levels