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Status of the Northwestern Atlantic Butterfish Stock - 1983

by

Gordon T. Waring and Emory D. Anderson

APPROVED FOR DISSEMINATION
Vaughn Anthony
(APPROVING OFFICIAL)
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(DATE)

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

SUMMARY

International landings of butterfish (Peprilus triacanthus) off the Atlantic Coast of the USA in 1982 totaled 9,700 metric tons (mt) and were the highest reported since 1976. This increase resulted largely from record high USA landings (8,900 mt) in response to a strong export market. Although the demand for butterfish remained high in 1983, domestic landings declined sharply (4,100 mt) due to decreased availability of large butterfish. The 1982 distant-water-fleet (DWF) landings (794 mt) declined 15% from 1981 (936 mt).

The USA August-December 1983 fishery was beset by a large influx of small (1983 year class; age 0) butterfish. As a result, estimated annual discard rates of 10% in the butterfish trawl fishery increased to 50% in the second half of 1983. Additionally, several processors began packing a new category of butterfish (supersmall). Several implications of this new category are, a decrease in yield per recruit, reduced recruitment to the age 1+ (spawning) stock, and increased harvesting of age 0 fish which may contribute to high discard rates.

Recruitment estimates (age 0) based on linear regression of autumn bottom trawl survey age 0 abundance indices and age 0 population estimates from cohort analysis indicate that the 1983 year class is the strongest observed since 1976. However, given the high levels of discard reported for this year class, recruitment to the age 1 and older stock, beginning in 1984, may be substantially reduced.

Stock biomass (ages 1 and older) declined from 15,800 mt in 1982 (the highest since 1976) to 10,400 mt in 1983, but increased 25% to an estimated 12,900 mt at the beginning of 1984. High levels of fishing mortality in 1982 on ages 0 and 1 fish and poor recruitment of the 1982 year class (age 1 in 1983) contributed to the 1983 decline. Recruitment of the strong 1983 year class (age 1 in 1984) and decreased 1983 landings account for the 25% stock increase in 1984.

Catch and stock projections indicate that a catch in 1984 of 7,100 mt ($F = 0.84$) would result in no change in the stock biomass from 1984 to 1985. Fishing at $F_{0.1} = 1.60$ in 1984 would produce a catch of 11,500 mt and decrease the 1985 stock 21% from 1984 and 2% from 1983. Catch and stock projections beyond 1985 are not prudent for butterfish since they are short-lived (about 4 years) thus, stock size is largely dependent on recruiting year classes.

INTRODUCTION

Butterfish (Peprilus triacanthus) occur along the east coast of North America from Newfoundland to Florida (Hildebrand and Schroeder 1928), and are commercially important between Cape Hatteras and Southern New England. The stock north of Cape Hatteras migrates inshore and northward during the summer and offshore and southward to the edge of the continental shelf in late autumn where overwintering occurs (Figures 1 and 2).

Butterfish were exploited exclusively by United States (USA) fishermen during 1920-62. Distant water fleets (DWF), initially from the USSR, began catching butterfish in 1963. Total nominal catch (live weight equivalent of landings exclusive of discards, hereafter referred to as landings) peaked at 19,500 metric tons (mt) in 1973, with over 90% taken by the DWF primarily as a by-catch in their squid fisheries. High levels of non-reported butterfish discard occurred in the DWF squid fisheries during the mid-1960's to mid-1970's. Since 1977, the fishery has been conducted principally by USA fishermen.

This document describes the current status of the Northweast Atlantic butterfish stock in NAFO (Northwest Atlantic Fisheries Organization) Subareas 5 and 6 based on an examination of research vessel survey data and commercial catch and effort data and an analytical assessment (cohort analysis) of commercial catch data.

MANAGEMENT HISTORY

Management of butterfish began during 1974-76 when it was combined with numerous other species in ICNAF's (International Commission for the Northwest Atlantic Fisheries) "Other Finfish" category and regulated by

an "Other Finfish" catch quota. ICNAF imposed a separate total allowable catch (TAC) of 18,000 mt for butterfish for 1977 (ICNAF 1977). Since March 1977, management of butterfish has been under USA jurisdiction governed by provisions of the Magnuson Fishery Conservation and Management Act of 1976 (MFCMA, Public Law 94-265). During February 1977, the National Marine Fisheries Service (NMFS) implemented a Preliminary Management Plan (PMP) for finfish caught incidental to the trawl fisheries of the Northwest Atlantic which included butterfish. Under the PMP, an optimum yield (OY) of 18,000 mt was established for butterfish. This PMP remained in effect until the Fishery Management Plan (FMP) for Atlantic Butterfish, prepared by the Mid-Atlantic Fishery Management Council (MAFMC), was approved, November 1979.

Under the FMP, management was changed from a calendar year to a fishing year (1 April 1979 - 31 March 1980) with an OY of 11,000 mt. Domestic annual harvest (DAH) was established at 7,000 mt with a total allowable level of foreign fishing (TALFF) of 4,000 mt. Amendment #1 to the FMP, approved March 1980, and Amendment #2, approved February 1981, extended the FMP through the fishing years 1980-81, 1981-82, and 1982-83, respectively. Amendment #3 (MAFMC 1981) received initial approval from NMFS in October 1982 and was implemented under an emergency interim rule on 1 April 1983. This amendment merged the butterfish FMP with similar FMP's for Atlantic mackerel and the squids (*Loligo* and *Illex*). Under Amendment #3, the butterfish TALFF would be 6% of the allocated portion of the *Loligo* squid TALFF plus 1% of the allocated *Illex* squid, Atlantic mackerel, silver hake, and red hake TALFF's. OY would equal the USA harvest plus TALFF, but could not exceed 16,000 mt.

On 15 September 1983 the MAFMC adopted Amendment #1 to the Fishery Management Plan for the Atlantic mackerel, squid, and butterfish fisheries (MAFMC 1983). This plan received Secretary approval on 7 February 1984. The OY and TALFF in Amendment #1 is identical to that described above for Amendment #3.

COMMERCIAL FISHERY

Landings

Total landings of butterfish in 1982 (9,699 mt) were the highest reported since 1976 (Table 1). Landings by the DWF declined from 936 mt in 1981 to 794 mt in 1982. Only 15% (184 mt) of the foreign allocation of 1,200 mt during the fishing year 1 April 1982 - 31 March 1983 from the TALFF of 4,000 mt was caught. The 1983 DWF landings were 630 mt.

USA landings increased dramatically (83%) from 4,855 mt in 1981 to a record high level of 8,905 mt in 1982, followed by a 54% decline to 4,126 mt in 1983. Decreased landings in 1983 have resulted from decreased availability of large marketable fish rather than lowered demand, as the export market presently remains strong.

Strong seasonal differences have existed between DWF and USA butterfish fisheries. DWF landings in 1982 occurred mostly during January-March (58%), whereas USA landings were predominantly during September-December (76%).

Discards

Based on information obtained from interviews conducted with several Pt. Judith, Rhode Island fishermen and processors, discards of small butterfish by USA fishermen prior to 1983 were approximately 10% of the annual mobile gear landings. In late summer 1983, however, components of the Pt. Judith fishery began reporting substantial quantities of discarded fish. Based on statistics collected by NMFS port agents, discards after mid-August averaged 50% by weight of the landed catch in the trawl fishery.

Based on the above information, discards during 1 January 1976-15 August 1983 from the USA trawl fishery for butterfish were assumed to be 10% by weight of the landed catch. Discard during 16 August - 31 December 1983 was considered to be 50% by weight of the trawl landings of butterfish at Pt. Judith (Table 1). Estimated discard during 1976-82 ranged between 107 mt (1977) and 784 mt (1982), and in 1983 increased to 1,150 mt.

Length and Age Composition of Catch

Length frequency data from DWF and USA landings in 1982 are presented in Figure 3. Samples from the DWF fishery were collected during the first and fourth calendar quarters of 1982. USA data encompass the entire year, but were obtained principally from autumn landings when the domestic fishery was at its peal. The DWF length frequencies ranged between 8 and 24 cm (fork length) with modes occurring at 12 cm and 15 cm, respectively. The USA length frequencies ranged from 12 to 22 cm and exhibited a pronounced mode at 16 cm. The dissimilarity in modes between the DWF

and USA length frequencies (Waring and Anderson, 1981) results from culling practices in the USA fishery and differences in location between the two fisheries (DWF offshore, USA inshore/offshore).

The USA food fishery length frequency data for 1981, 1982, and 1983 are compared in Figure 4. Size distributions are similar among years; a single pronounced mode ranging between 15 and 19 cm is evident in each year. The mode in 1983 was at 18 cm, compared to 18 and 16 cm, respectively, in 1981 and 1982. This implies that the 1983 landings may have included a higher proportion of older fish (e.g., ages 2-3) than in 1982.

The age compositions of the 1982 DWF and USA landings were estimated by applying quarterly age/length keys derived from commercial samples and 1982 NEFC spring and autumn bottom trawl survey samples to the DWF and USA length frequencies from the respective months. In both periods, the DWF landings contained proportionally more younger fish than the USA landings (Table 2). Furthermore, both fisheries caught a high proportion of age 1-2 fish during the January-June period, whereas during July-December, the age composition shifted towards age 0-1 fish. This shift represents the greater availability of younger age groups later in the year due to recruitment of age 0 fish to the fishery and growth of the age 1 fish.

Landings-at-age data for the 1976-82 international fishery are given in Table 3 by 6-month periods. Data for years prior to 1976 are not reliable due to the lack of age/length keys for most years.

Estimated discards (weight) in the USA fishery during January-July and August-December of each year were assigned to age groups 1 and 0, respectively. Estimated numbers at age discarded during 1976-82 were obtained by applying mean weights (Table 4) to the estimated weight of the discard are given in Table 3. Age 0 fish accounted for most of the discards, particularly after 1979, reflective of higher landings in the latter half of the year.

Mean Weight at Age

Mean weights at age for the 1982 landings (USA and DWF) are given in Table 4. These values were determined by applying a length/weight equation developed by Kawahara (1977) to the age/length composition of the 1982 landings.

Mean weights at age for the discard (ages 0 and 1) (Table 4) were estimated by applying Kawahara's (1977) length/weight equation to the length composition of discard samples collected in 1983. In the absence of additional information, these mean weights were assumed for the discard in all years.

Stock mean weights at ages 1 and older (Table 4) were derived by applying Kawahara's (1977) length/weight equation to the average age/length composition of catches from the NEFC spring surveys in 1980-82. Stock mean weight at age 0 was obtained in the same way using autumn survey data from 1980-82.

Effort and Catch Per Unit Effort

Annual effort and catch per unit effort (CPUE) were derived for 1967-82 from trips by USA otter trawlers in which butterfish accounted for 50% or more of the landed catch. Catch and effort were principally from tonnage class 3 vessels (51-150 gross registered tonnage) which have dominated the fishery.

From 1967 to 1977, USA directed effort was relatively low, remaining below 100 days per year (Figure 5). Since 1978, a substantial increase in directed effort occurred coincident with the implementation of the MFCMA and expanding export market opportunities for USA-caught butterfish. Presently, the market for butterfish remains strong which should maintain effort in the range observed in recent years.

CPUE has increased rapidly since 1978, reaching a high of 19.4 mt per day in 1982 (Figure 5). Even though effort has remained high in 1983, CPUE is expected to decline since it refers to landed catches which have declined while discarded catches have increased markedly.

Total international effort, expressed as equivalent USA days fished, was determined for 1976-82 by 6-month periods (January-June and July-December) by dividing international landings by USA CPUE (Table 5). International effort dropped sharply from 1976 to 1977. During 1978-82, effort was approximately twice as high during July-December as during January-June due to the bulk of the USA fishery occurring during the latter half of the year. Total annual effort was relatively stable during 1978-80, but underwent about a 15% decrease in 1981-82.

SURVEY ABUNDANCE INDICES

Indices of relative abundance and biomass (number and weight) were derived from NMFS, NEFC autumn bottom trawl survey (Grosslein, 1969) catch-per-tow data from a combination of offshore (>27 m depth) (1-14, 16, 19, 20, 23, 25, and 61-76, Figure 6) and inshore (1-46, Figure 7) sampling strata (Waring and Anderson, 1982).

The survey number-per-tow index in 1983 (396.2) increased 266% from the 1982 value and was the highest index in the 1968-83 time-series (Table 6). The weight-per-tow index in 1983 (11.4 kg) increased 143% from 1982 and was the third highest observed in the 16-year time-series.

The age composition of the 1983 autumn survey length frequencies was derived by using 1982 autumn age/length keys, as 1983 age/length keys were not available.

The recruitment index (number per tow at age 0) from the 1983 autumn survey (300.0) was the highest observed in the 16-year time-series and represents the fourth strong year class in the past five years (Table 7).

The number-per-tow index for age 1 and older butterfish increased nearly fourfold in 1983 (96.3) above the 1982 index (26.6).

Length frequencies of the mean catch per tow for butterfish from autumn bottom trawl surveys for 1981-83 are plotted in Figure 8. Age 0 (young-of-year) fish are characterized by a strong mode at 10-14 cm which corresponds to fish spawned in late spring. A mode at 14-18 cm is principally a reflection of age 1 fish, with some contribution from ages 2 and 3. Additionally, the size composition of fish in 1983 is smaller than that observed in 1981 and 1982, reflecting the presence of a very strong 1983 year class.

FISHING MORTALITY

Instantaneous fishing mortality (F) rates for butterfish were estimated for 1976-82 using cohort analysis (Pope, 1972). Cohort analysis was applied to numbers-at-age catch data partitioned into 6-month intervals (Table 3). Because of the short life span of butterfish, this partitioning provided nine age groups (coded ages 0-8) instead of five (ages 0-4) and facilitated the estimation of terminal F for each year class and provided greater insight into the within-year mortality pattern.

The annual instantaneous natural mortality (M) rate for butterfish has been assumed to be 0.8 (Murawski and Waring, 1979). An M of 0.4 was assumed for each 6-month period.

A number of initial cohort analyses were performed for the 1973-79 year classes using terminal F's at coded age 8 ranging from 0.20 to 1.20 to determine the effect of different terminal F's on the F's at younger ages and to identify the general pattern of F by age and year. The results from these initial cohort analyses indicated that (1) the choice of the terminal F had little effect on the F values calculated for earlier age groups as convergence occurred rapidly because of the high F values involved, and (2) within each 6-month period of each calendar year, F consistently increased with age. Based on this latter trend, a terminal F of 1.00 was chosen for the 1973-75 year classes, and an F of 0.80 was assumed for the 1976-78 year classes (Table 8).

The terminal F values for the 1979 and 1980 year classes in 1982 were predicted from a relationship between fishing effort and mean F at coded ages 3 and older. Having performed cohort analysis on the 1973-78 year classes using the terminal F values indicated above, cohort analysis was also done on the 1979 year class using a trial terminal F value at coded age 6 in 1982. Weighted mean F values at coded ages 3 and older during January-June and at coded ages 4 and older during July-December were calculated for each year during 1976-81. A geometric mean (GM) functional regression (Ricker 1973) was calculated between international effort for each 6-month period from July-December 1976 to July-December 1981 (Table 5) and the corresponding mean F values. Mean F at coded ages 4 and older during July-December 1982 was predicted from this regression (Figure 9). F values at coded ages 6 (1979 year class) and 4 (1980 year class) during July-December 1982 were derived from this predicted mean F in proportion to the geometric mean of the ratios between coded age 6 and mean F at coded ages 4 and older and between coded age 4 and mean F at coded ages 4 and older during 1978-81. Cohort analysis was run on the 1979 and 1980 year classes using the terminal F values thus estimated, mean F's at coded ages 3 and older (January-June) and coded ages 4 and older (July-December) were recalculated, and a new functional regression determined. This procedure was carried through several iterations until the mean F predicted from the regression for July-December 1982 remained unchanged from the mean F used in the previous cohort analysis. A mean F of 0.508 was thus predicted for coded ages 4 and older in July-December 1982 (Table 8). F at coded ages 4 and 6 was determined, as described above, to be 0.49 and 0.62, respectively.

F values at age 0 in 1981 and 1982 were derived from estimated year-class sizes and known catches at age 0. F values at coded ages 1 and 2 during January-June and July-December 1982, respectively, were also derived from known catches and the estimated size of the 1981 year class.

The F values estimated for 6-month periods were summed into yearly values by age group 0-4 (Table 9). Mean F at ages 2 and older, after dropping from 2.14 in 1976 to 0.91 in 1977, underwent a steady increase to 1.04 in 1981 and then declined to 0.77 in 1982.

RECRUITMENT

The sizes of the 1976-80 year classes at age 0 estimated from cohort analysis ranged from 164.6 million (1977 year class) to 329.4 million (1980 year class) (Table 9). Estimates of the size of the 1981-83 year classes were made from a linear regression between autumn survey catch per tow at age 0 and year-class size at age 0 from cohort analysis for the 1976-80 year classes (Figure 10). The 1983 year class was estimated to be the strongest observed at 348 million, followed by the 1981 (303 million) and 1982 (207 million) year classes. For the purposes of catch and stock size projections, the 1984 year class was assumed equal to the mean of the 1976-83 year classes (268.7 million).

EXPLOITATION PATTERN

The exploitation pattern by age of the 1976-82 butterfish fishery is described in Table 10. For each calendar year, the age-specific F values are expressed as a proportion of the mean F at ages 2 and older.

Results indicated a fairly consistent exploitation pattern during 1976-81 with GM proportions (selection factors) of 0.05, 0.25, 0.85, 1.57, and 2.02 at ages 0-4, respectively.

However, in 1982, this pattern deviated sharply at ages 0 and 1, increasing to 0.30 and 0.98 as a result of a substantial increase in the fishing mortality on age 0 and 1 fish by the USA fishery. This increased mortality on age 0 and 1 fish resulted from a heavy market demand in 1982 for butterfish. The demand for small (particularly age 0) butterfish remained strong in 1983.

For purposes of projecting the anticipated catch in 1983 and for projecting catch options in 1984, the mean (GM) of the 1981-82 exploitation patterns was used.

STOCK BIOMASS

Age-specific stock size estimates from cohort analysis are given in Table 9. Annual stock biomass estimates for 1976-83 were determined by applying mean weights at age (Table 4) to the stock size estimates.

Total stock biomass (ages 0 and older) decreased from 30,700 mt in 1976 to 16,600 mt in 1977 and increased steadily to 23,000 mt in 1980 (Table 9). Biomass declined after 1980 to 19,100 mt in 1983.

Biomass of the age 1 and older stock dropped from 25,000 mt in 1976 to 10,900 mt in 1978, recovered to 15,800 mt in 1982, and then dropped 35% to 10,400 mt in 1983.

YIELD PER RECRUIT

Yield-per-recruit calculations were made using the Ricker (1958) model. The selection factors used for ages 0-4 were the GM values for 1981-82 (Table 10). The mean weights used for ages 0-4 were those used in projecting the 1984 catch (Table 4). The resulting yield-per-recruit curve (Figure 11) was asymptotic, with no clearly defined maximum but with an $F_{0.1}$ (fishing mortality rate at which the increase in yield per recruit for a small increase in F is only 10% of that which would occur for the same increase in F in a virgin fishery) of 1.60. This level of F is considerably higher than any observed in the fishery since 1976.

CATCH AND STOCK PROJECTIONS

1983 Catch and 1984 Stock

The anticipated landings in 1983 were projected assuming the same mean weights at age as in 1982 (Table 4) and an exploitation pattern equivalent to the geometric mean of the 1981-82 patterns (Table 10), with the selection factors for ages 0 and 1 decreased from 0.15 and 0.45 to 0.04 and 0.40, respectively. These reductions reflect the proportion of the total catch at ages 0 and 1 during 1981-82 which was landed. A mean F of 0.671 at ages 2 and older was required to generate the anticipated landings of 4,650 mt by the USA and DWF.

The anticipated discard in 1983 of 1,150 mt of age 0 and 1 butterfish was projected assuming mean weights at age as given in Table 4, selection factors which would result in discards of age 1 fish equivalent to 10% of the landed catch in the USA butterfish trawl fishery during 1 January-15 August and discards of age 0 fish equivalent to 50% of the landed catch during 16 August-31 December, and a mean F of 0.671 at ages 2 and older.

The resulting selection factors were 0.30 and 0.54 at ages 0 and 1, respectively.

Based on total projected catch of 5,800 mt in 1983, the estimated stock biomass of age 1 and older butterfish at the beginning of 1984 would be 12,900 mt, a 25% increase from 1983.

1984 Catch and 1985 Stock

The catch in 1984 and resulting stock biomass (ages 1 and older) in 1985 were projected for a range of fishing mortality rates (Table 11, Figure 12). These projections were made assuming an exploitation pattern equal to the geometric mean of the 1981-82 patterns (Table 10) and mean weights at age (Table 4) applicable to a fishery with 10% discard rates for both age 0 and 1 fish. A catch in 1984 equal to the anticipated 1983 level (5,800 mt) would result in an F (0.65) approximately the same as projected for 1983 (0.67) and leave an age 1 and older stock of about 13,700 mt at the beginning of 1985 (6% increase from 1984). A catch of 7,100 mt (F = 0.84) in 1984 would leave a stock in 1985 equal to that in 1984 (12,900 mt). Fishing at $F_{0.1}$ = 1.60 would result in a catch of 11,500 mt in 1984 and a stock of 10,200 mt in 1985 (21% decrease from 1984 and 2% decrease from 1983).

DISCUSSION

The international butterfish catch increased from a recent low of about 3,900 mt in 1979 to 10,500 mt in 1982, the highest catch since 1976. The 1982 catch included record high landings of 8,900 mt by the USA fishery as well as an estimated 800 mt of discard by the USA fishery.

The rapid rise in USA landings was stimulated by a strong export market and supported by a 45% increase in stock biomass (ages 1 and older) from 1978 to 1982.

The recent increase in stock biomass was due to a succession of strong year-classes (1979-81). Over 50% of the catch in weight in 1982 consisted of age 1 fish (1981 year class). The fishing mortality rate on age 1 fish in 1982 was three times higher than the 1977-81 average at that age. The 1982 year class at age 0 was one of the poorest observed. However, the catch in numbers at age 0 in 1982, 75% of which was discard, was nearly twice as large as any observed since 1976, and resulted in an F about three times greater than the 1977-81 average at that age.

Despite favorable market conditions, landings declined by about 50% from 1982 to 1983 due to a sharp decline in stock size, primarily at ages 1 and 2. This decline was due to the unusually high fishing mortality rates at ages 0 and 1 in 1982, coupled with a weak 1982 year class. Stock biomass (ages 1 and older) decreased about 35% from 1982 to 1983. The 1983 year class at age 0 was, however, estimated to be the strongest observed in the 1976-83 time series. Discards of small butterfish in the USA fishery in 1983 reached an estimated high of about 1,150 mt. In addition, greater amounts of small butterfish were landed in 1983 than previously because of increased market demand. If this market demand continues, mortality on and catches of age 0 fish will remain high in the near future.

Despite the high discard rates in 1983, stock biomass (ages 1 and older) at the beginning of 1984 was estimated to be about 25% higher than in 1983, because of the strong 1983 year class. However, if discard rates of age 0 in 1983 had only been 10% of the landed catch, as estimated for 1976-82, instead of 50%, stock biomass in 1984 would have been about 38% higher than in 1983. Because butterfish have a short life span (about 4 years) and a relatively high annual natural mortality rate (M = 0.8), the fishery must, of necessity concentrate primarily on age 1 and 2 fish. Delaying fishing beyond age 1 will result in a decrease in yield per recruit due to the high natural mortality. However, excessive levels of fishing mortality at age 0 (through discard) will have an adverse effect on yield. If fishing is delayed until age 1, the gain in weight through growth will be greater than the loss in weight through natural mortality.

Concerning the fishery in 1984, under the assumptions of an average 1984 year class, an exploitation pattern comparable to the 1981-82 mean, and a 10% discard rate, catches can increase to about 7,100 mt (compared to about 5,800 mt in 1983) without resulting in a decrease in stock biomass (ages 1 and older) in 1985. If fishing mortality is increased to $F_{0.1}$ = 1.60 in 1984, well above recent levels, the catch would be about 11,500 mt and stock biomass would decrease about 20% from 1984 to 1985. However, if discard rates on small fish remain as high in 1984 as in 1983 (50%), stock biomass levels in 1985 will be much less than projected.

Future levels of catch will be largely dependent on the size of recruiting year classes. Increasing stock biomass and future catches can be enhanced by reducing the catch of age 0 butterfish to minimal levels.

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Table 1. Nominal catch (metric tons) of butterfish from Northwest Atlantic Fisheries Organization (NAFO) Subareas 5 and 6 by country, 1963-83.

Year	USA	Japan	USSR	Poland	Spain	Italy	Bulgaria	GDR	Romania	Others	Nominal catch	Adjusted[1] nominal catch
1963	4,513	-	2,285	-	-	-	-	-	-	-	6,798	6,798
1964	2,461	-	748	-	-	-	-	-	-	-	3,209	3,209
1965	3,340	-	749	-	-	-	-	-	-	-	4,089	4,089
1966	2,615	-	3,865	-	-	-	-	-	-	-	6,480	6,480
1967	2,452	146	2,170	-	-	-	-	-	-	-	4,768	4,768
1968	1,804	3,526	1,911	-	-	-	-	-	-	-	7,241	7,241
1969	2,438	3,930	11,107	-	-	-	36	-	-	-	17,511	17,816
1970	1,869	8,624	404	-	-	-	-	-	-	-	10,897	14,319
1971	1,570	5,771	486	-	-	-	26	-	-	-	7,853	10,483
1972	819	3,675	1,848	-	-	-	114	34	-	-	6,490	13,040
1973	1,557	12,172	2,334	2,804	-	-	239	196	152	-	19,454	33,236
1974	2,528	5,457	1,372	3,508	-	-	-	-	-	-	12,865	17,993
1975	2,088	3,624	789	3,754	-	-	298	1	-	612[2]	11,165	14,852
1976	1,528	7,884	420	1,518	-	-	4	3	62	-	11,419	15,965
1977	1,448	1,741	419	280	117	107	-	-	16	525[3]	4,653	4,760
1978	3,676	657	14	-	124	355	-	-	83	93[4]	5,002	5,375
1979	2,831	263	2	-	83	139	-	-	10	343[5]	3,671	3,938
1980	5,356	660	-	3	59	73	-	-	3	81[6]	6,235	6,748
1981	4,855	574	-	-	255	107	-	-	-	-	5,791	6,255
1982	8,905	434	-	-	183	177	-	-	-	-	9,699	10,483
1983[7]	4,126	212	-	-	69	349	-	-	-	-	4,756	5,906

[1] Adjusted to account for non-reported discards of countries not reporting butterfish from directed Loligo fishing operations (Murawski and Waring, 1979). The 1976-83 adjusted landings incorporate estimated discards in the USA fishery.

[2] Ireland.

[3] Ireland-415, Cuba-110.

[4] Mexico.

[5] Mexico

[6] Cuba-9, Mexico-72.

[7] Updated February 1984.

Table 2. Age composition of the 1982 USA and DWF butterfish landings.

Period	Fishery	Percent age					Tons
		0	1	2	3+	Total	
Jan-Jun	USA	-	25	54	21	100	1751
	DWF	-	65	27	8	100	382
Jul-Dec	USA	5	72	19	4	100	7154
	DWF	81	14	5	0	100	412

Table 3. Butterfish landings, discards, and catch at age (millions) 1976-82.

		Age in months/Coded age									Total	
		1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54		
Year	Months	0	1	2	3	4	5	6	7	8	Numbers	Tons
						Landings in numbers (millions)						
1976	1- 6		68.70		70.97		18.55		3.06		161.28	12821.4
	7-12	0.82		15.87		13.40		1.29		-	31.38	3015.6
1977	1- 6		2.87		22.03		4.97		-		29.87	3182.4
	7-12	6.87		11.64		1.50		0.61		-	20.62	1470.6
1978	1- 6		5.16		7.28		2.88		0.17		15.49	1549.5
	7-12	6.03		6.57		13.83		2.96		0.10	29.49	3452.5
1979	1- 6		4.41		4.40		5.10		0.94		14.85	1479.4
	7-12	7.67		4.41		6.37		1.66		0.10	20.21	2191.6
1980	1- 6		15.03		7.02		2.58		0.68		25.31	1491.4
	7-12	1.70		26.54		14.98		1.44		0.02	44.68	4743.6
1981	1- 6		6.10		8.50		4.76		0.60		19.96	2090.2
	7-12	4.56		13.61		13.41		1.29		0.10	32.97	3700.8
1982	1- 6		8.71		11.75		3.25		0.62		24.33	2199.9
	7-12	9.27		46.58		13.11		1.69		0.04	70.69	7499.6
						Discards in numbers (millions)						
1976	1- 6		2.54		-		-		-		2.54	66.0
	7-12	2.59		-		-		-		-	2.59	62.2
1977	1- 6		1.38		-		-		-		1.38	35.9
	7-12	2.95		-		-		-		-	2.95	70.8
1978	1- 6		4.94		-		-		-		4.94	128.4
	7-12	10.19		-		-		-		-	10.19	244.6
1979	1- 6		5.43		-		-		-		5.43	141.2
	7-12	5.23		-		-		-		-	5.23	125.6
1980	1- 6		3.34		-		-		-		3.34	86.9
	7-12	17.77		-		-		-		-	17.77	426.4
1981	1- 6		5.36		-		-		-		5.36	139.3
	7-12	13.52		-		-		-		-	13.52	324.4
1982	1- 6		6.06		-		-		-		6.06	157.5
	7-12	26.10		-		-		-		-	26.10	626.4
						Catch in numbers (millions)						
1976	1- 6		71.24		70.97		18.55		3.06		163.82	12887.4
	7-12	3.41		15.87		13.40		1.29		-	33.97	3077.8
1977	1- 6		4.25		22.03		4.97		-		31.25	3218.3
	7-12	9.82		11.64		1.50		0.61		-	23.57	1541.4
1978	1- 6		10.10		7.28		2.88		0.17		20.43	1677.9
	7-12	16.22		6.57		13.83		2.96		0.10	39.68	3697.1
1979	1- 6		9.84		4.40		5.10		0.94		20.28	1620.6
	7-12	12.90		4.41		6.37		1.66		0.10	25.44	2317.2
1980	1- 6		18.37		7.02		2.58		0.68		28.65	1578.3
	7-12	19.47		26.54		14.98		1.44		0.02	62.45	5170.0
1981	1- 6		11.46		8.50		4.76		0.60		25.32	2229.5
	7-12	18.08		13.61		13.41		1.29		0.10	46.49	4025.2
1982	1- 6		14.77		11.75		3.25		0.62		30.39	2357.4
	7-12	35.37		46.58		13.11		1.69		0.04	96.97	8125.5

Table 4. Mean weights of age (kg) for butterfish in the Northwest Atlantic.

Category	Age 0	1	2	3	4
Landings (1982)	.060	.092	.105	.130	.165
Discard (1976-83)	.024	.026	-	-	-
Catch (1984)	.045	.085	.105	.130	.165
Stock (1976-85)	.025	.045	.080	.120	.155

Table 5. International landings (C), USA CPUE (mt/day), and international effort (f) expressed as equivalent USA days fished.

Year	Jan-Jun C	Jan-Jun CPUE	Jan-Jun f	Jul-Dec C	Jul-Dec CPUE	Jul-Dec f
1976	12821.4	2.20	5827.9	3015.6	3.69	817.2
1977	3182.4	7.66	415.5	1470.6	5.05	291.2
1978	1549.5	8.83	175.5	3452.5	8.64	399.6
1979	1562.4	7.64	204.5	2198.6	6.12	359.2
1980	1491.4	6.79	219.6	4743.6	13.05	363.5
1981	2090.2	14.16	147.6	3700.8	11.85	312.3
1982	2199.9	13.12	167.7	7499.6	22.59	332.0

Table 6. Indices of relative abundance and biomass (stratified mean catch per tow) for butterfish derived from NEFC autumn bottom trawl survey data, 1968-83[1].

Year	Numbers	Weight (kg)
1968	93.6	7.7
1969	61.6	3.9
1970	39.3	2.3
1971	218.6	4.3
1972	81.9	2.7
1973	148.4	6.1
1974	100.2	3.8
1975	45.7	2.3
1976	139.6	5.8
1977	87.0	5.2
1978	142.5	4.3
1979	309.6	12.1
1980	332.9	15.2
1981	294.7	7.0
1982	108.3	4.7
1983	396.2	11.4

[1]Strata 1-12, 61-76, 13, 14, 16, 19, 20, 23, 25 (offshore); 1-46 (inshore).

Table 7. Indices of relative abundance (stratified mean catch per tow) for butterfish by age group derived from NEFC autumn bottom trawl survey data, 1968-83[1].

Year	Age 0	Age 1 and older
1968	41.3	52.3
1969	39.5	21.1
1970	27.1	12.2
1971	209.0	9.6
1972	73.2	8.7
1973	119.1	29.3
1974	82.2	18.0
1975	26.3	19.4
1976	110.6	29.0
1977	47.7	39.3
1978	127.0	15.5
1979	288.7	20.9
1980	228.5	104.4
1981	229.9	64.8
1982	81.7	26.6
1983	300.0	96.3

[1]Strata 1-12, 61-76, 13, 14, 16, 19, 20, 23, 25 (offshore); 1-46 (inshore).

Table 8. Fishing mortality and stock size for Northwest Atlantic butterfish estimated at 6-month intervals (M=0.40) by cohort analysis.

		Age in months/Coded age									
		1-6	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-54	
Year	Months	0	1	2	3	4	5	6	7	8	
						Fishing mortality					Mean F[1]
1976	1- 6		.446		1.107		1.993		2.500		1.286
	7-12	.018		.207		.845		1.000		-	.857
1977	1- 6		.033		.646		1.327		-		.733
	7-12	.076		.149		.097		.708		-	.139
1978	1- 6		.128		.163		.344		.559		.196
	7-12	.085		.143		.697		.993		1.000	.741
1979	1- 6		.083		.166		.807		1.637		.361
	7-12	.051		.060		.496		.924		1.000	.561
1980	1- 6		.119		.159		.491		2.637		.232
	7-12	.075		.318		.793		.751		.800	.789
1981	1- 6		.071		.197		.853		1.190		.308
	7-12	.075		.139		.718		.785		.800	.724
1982	1- 6		.099		.214		.477		1.933		.265
	7-12	.229		.660		.490		.620		.800	.508
						Stock size (millions)					
1976	1- 6		241.75		129.48		26.23		3.76		
	7-12	239.83		103.72		28.69		2.40		-	
1977	1- 6		157.97		56.53		8.26		-		
	7-12	164.63		102.41		19.86		1.47		-	
1978	1- 6		102.31		59.12		12.08		0.49		
	7-12	243.71		60.31		33.67		5.74		0.19	
1979	1- 6		150.08		35.05		11.25		1.43		
	7-12	314.23		92.55		19.89		3.36		0.19	
1980	1- 6		200.07		58.43		8.12		0.90		
	7-12	329.43		119.07		33.42		3.33		0.04	
[2]1981	1- 6		204.88		58.09		10.14		1.05		
	7-12	303		127.96		31.98		2.90		0.22	
[2]1982	1- 6		188.36		74.63		10.46		0.89		
	7-12	207		114.36		40.40		4.35		0.09	
[2,3]1983	1- 6		110.43		39.62		16.59		1.57		
	7-12	348									

[1]Weighted mean for coded ages 3 and older.

[2]Recruitment at age 0 calculated from autumn bottom trawl survey age 0 abundance indices.

[3]1983 stock size at age 1 and older determined from catch equation $N_{i+1} = N_{ie}^{-Z_i}$.

Table 9. Catch, fishing mortality, and stock size for Northwest Atlantic butterfish.

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Total Numbers	Total Tons
	Catch in numbers (millions)						
1976	3.41	87.11	84.37	19.84	3.06	197.79	15965.2
1977	9.82	15.89	23.53	5.58	-	54.82	4759.7
1978	16.22	16.67	21.11	5.84	0.27	60.11	5375.0
1979	12.90	14.25	10.77	6.76	1.04	45.72	3937.8
1980	19.47	44.91	22.00	4.02	0.70	91.10	6748.3
1981	18.08	25.07	21.91	6.05	0.70	71.81	6254.7
1982	35.37	61.35	24.86	4.94	0.66	127.18	10482.9

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Mean F (Age 2 and older)
	Fishing mortality					
1976	.018	.653	1.952	2.993	2.500	2.136
1977	.076	.182	.743	2.035	-	.908
1978	.085	.271	.860	1.337	1.559	.945
1979	.051	.143	.662	1.731	2.637	.973
1980	.075	.437	.952	1.242	3.437	1.020
1981	.075	.210	.915	1.638	1.990	1.037
1982	.229	.759	.704	1.097	2.733	.773

Year	Age 0	Age 1	Age 2	Age 3	Age 4	Total (Age 0 and older) Numbers	Total (Age 0 and older) Tons	Total (Age 1 and older) Numbers	Total (Age 1 and older) Tons
	Stock size (millions)								
1976	239.83	241.75	129.48	26.23	3.76	641.05	30,723	401.22	24,968
1977	164.63	157.97	56.53	8.26	-	387.39	16,573	222.76	12,622
1978	243.71	102.31	59.12	12.08	0.49	417.71	16,952	174.00	10,859
1979	314.23	150.08	35.05	11.25	1.43	512.04	18,985	197.81	11,129
1980	329.43	200.07	58.43	8.12	0.90	596.95	23,027	267.52	14,791
[1]1981	303.00	204.88	58.09	10.14	1.05	577.04	22,818	274.16	15,246
[1]1982	207.00	188.36	74.63	10.46	0.89	481.47	21,018	274.34	15,840
[1,2]1983	348.00	110.43	39.62	16.59	1.57	516.04	19,069	168.21	10,373

[1]Recruitment at age 0 calculated from autumn bottom trawl survey age 0 abundance indices.

[2]Stock size at age 1 and older calculated from the relationship, $N_{i+1} = N_i e^{-Zi}$.

Table 10. Selection factors at age for butterfish, 1976-82.

Year	Age 0	1	2	3	4
1976	.008	.306	.914	1.401	1.170
1977	.084	.200	.818	2.241	-
1978	.090	.287	.910	1.415	1.650
1979	.052	.147	.680	1.779	2.710
1980	.074	.428	.933	1.218	3.370
1981	.072	.203	.882	1.580	1.919
1982	.296	.982	.911	1.419	3.536
1976-81 GM	.051	.246	.851	1.574	2.022
1981-82 GM	.146	.446	.896	1.497	2.605

Table 11. Projected catch in 1984 (ages 0 and older) and resultant stock biomass in 1985 (ages 1 and older) for a range of fishing mortality rates. Catch and stock biomass are expressed as thousands of mt.

Stock in 1984	F in 1984	Catch in 1984	Stock in 1985
12.90	0.2	2.03	16.16
12.90	0.4	3.83	15.01
12.90	0.6	5.43	13.98
12.90	0.8	6.88	13.06
12.90	1.0	8.19	12.24
12.90	1.2	9.38	11.50
12.90	1.4	10.48	10.82
12.90	($F_{0.1}$) 1.6	11.47	10.20
12.90	1.8	12.42	9.64
12.90	2.0	13.28	9.12
12.90	2.2	14.09	8.65
12.90	2.4	14.84	8.21

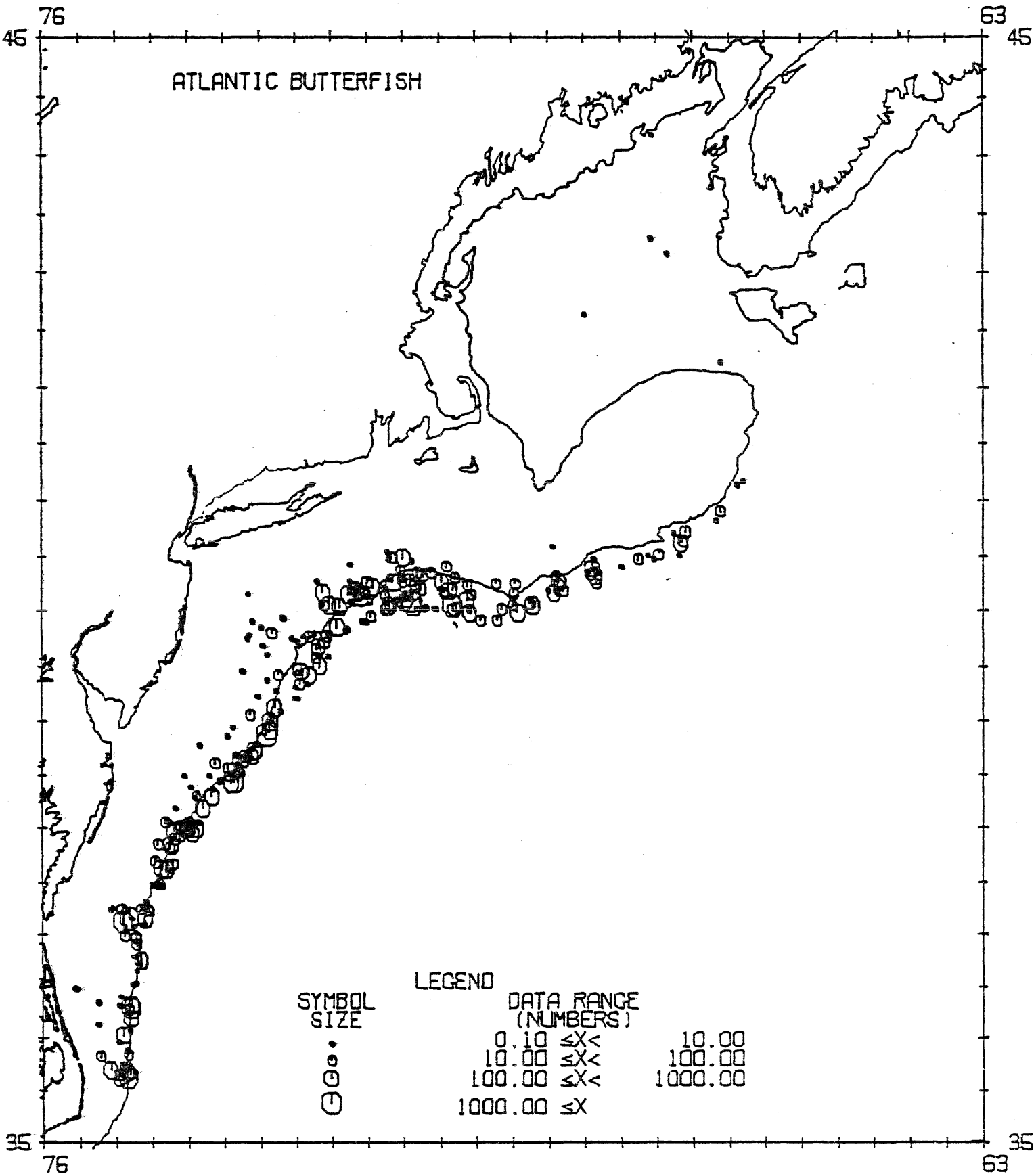


Figure 1. Spring distribution of butterfish based on 1976-1980 NMFS/NEFC offshore (>27 meters) bottom trawl surveys.

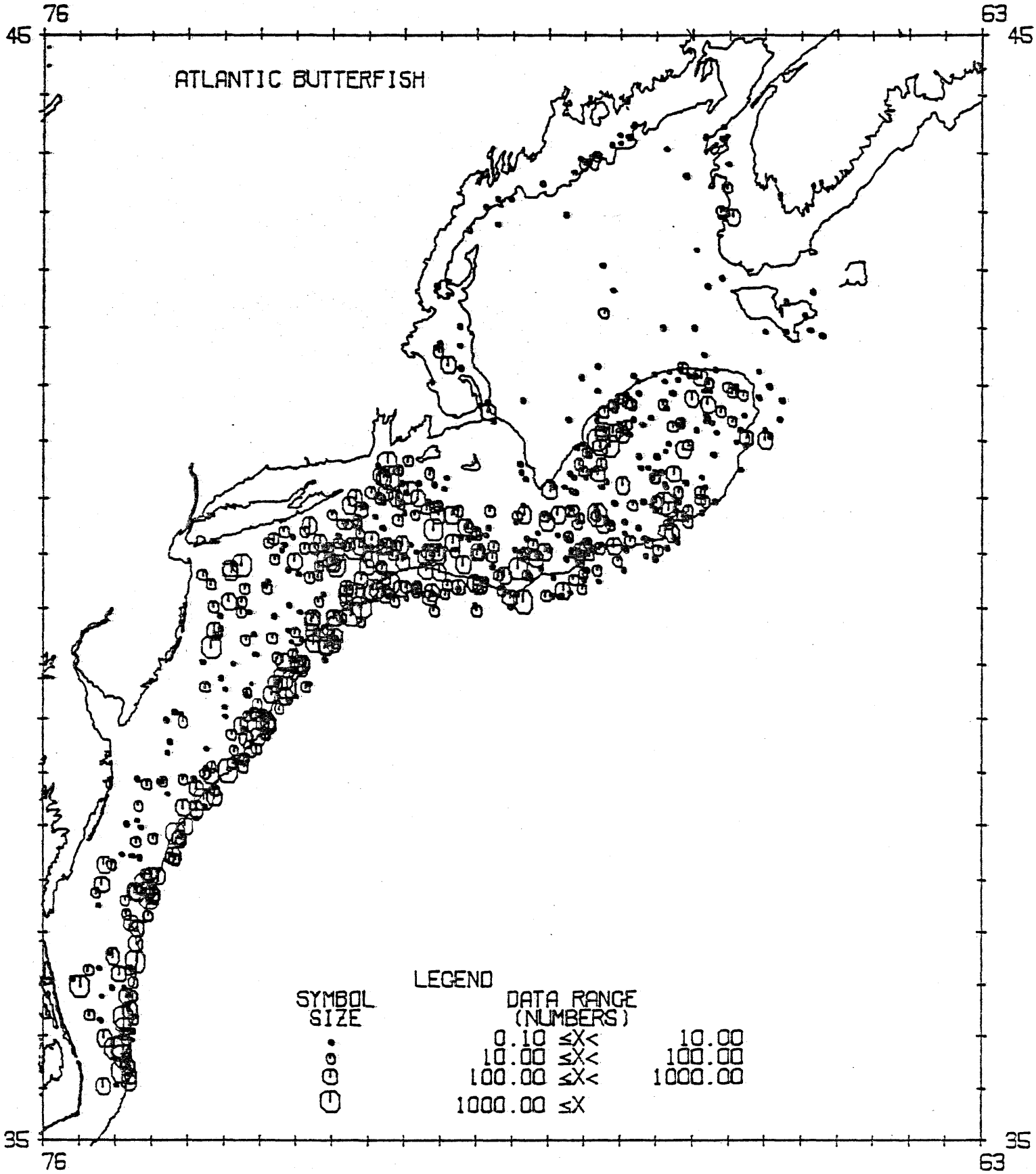


Figure 2. Autumn distribution of butterfish based on 1976-1980 NMFS/NEFC offshore (>27 meters) bottom trawl surveys.

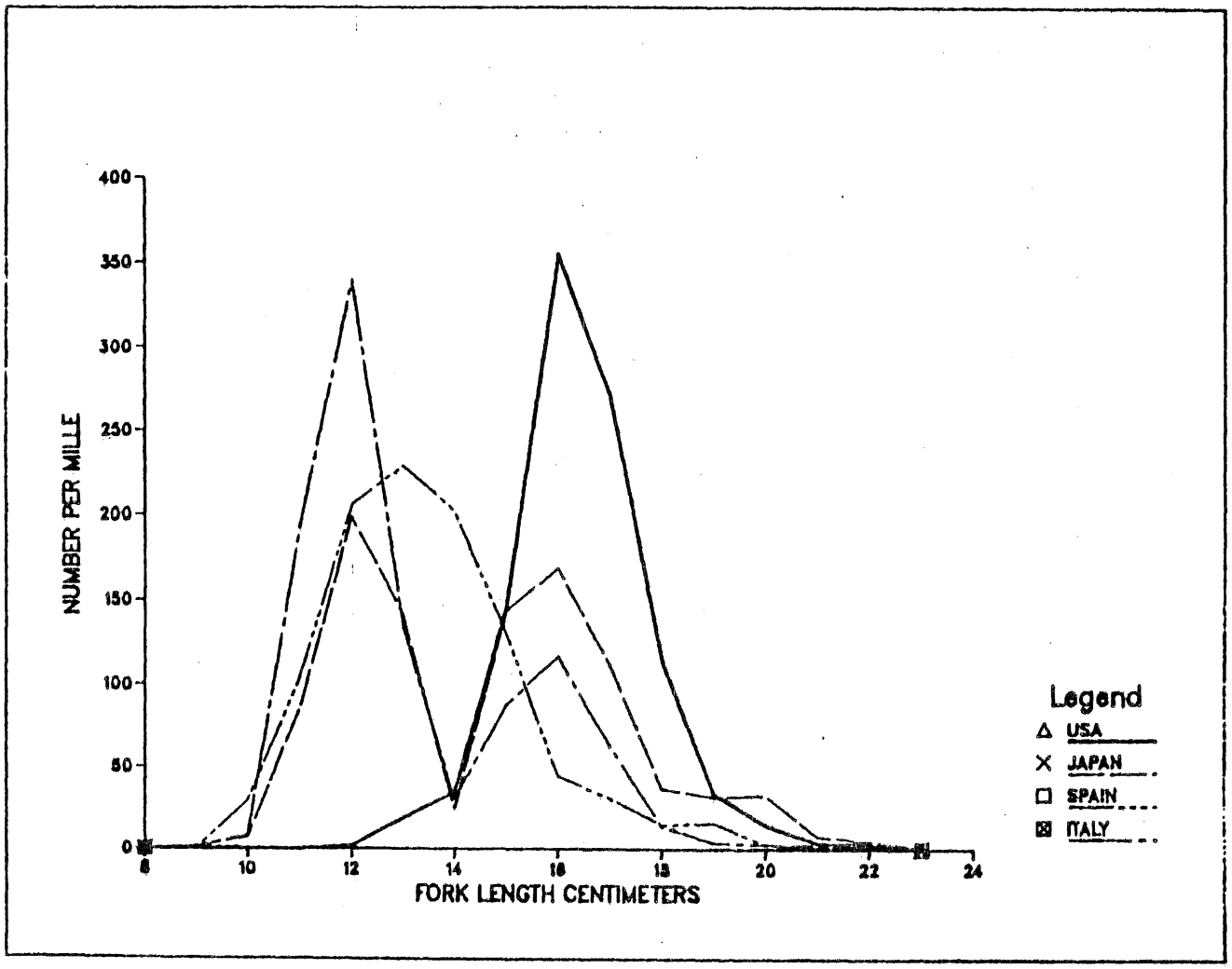


Figure 3. Butterfish length frequencies from sampling of commercial landings by country for 1982.

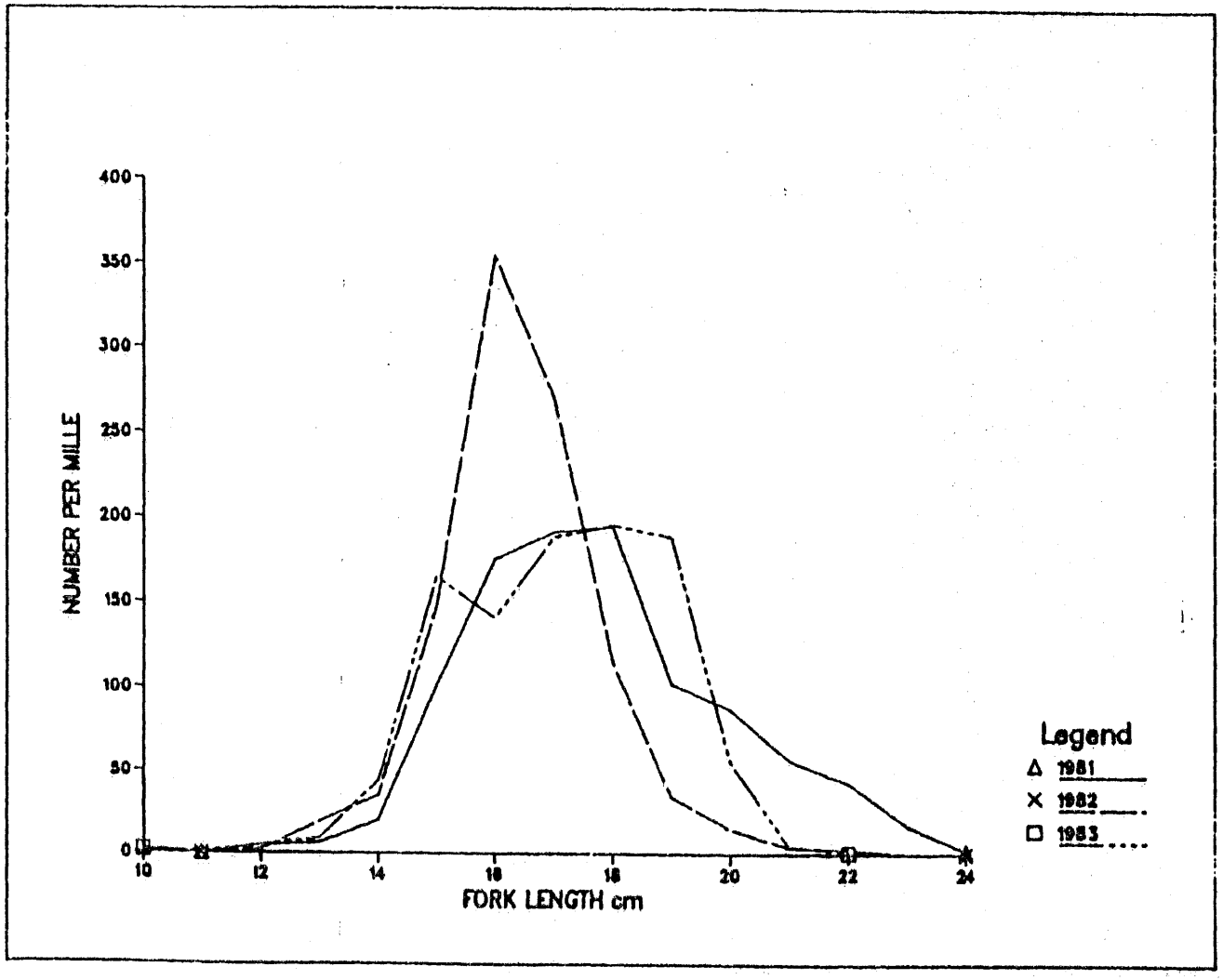


Figure 4. Butterfish length frequencies from sampling of USA commercial landings, 1981-1983.

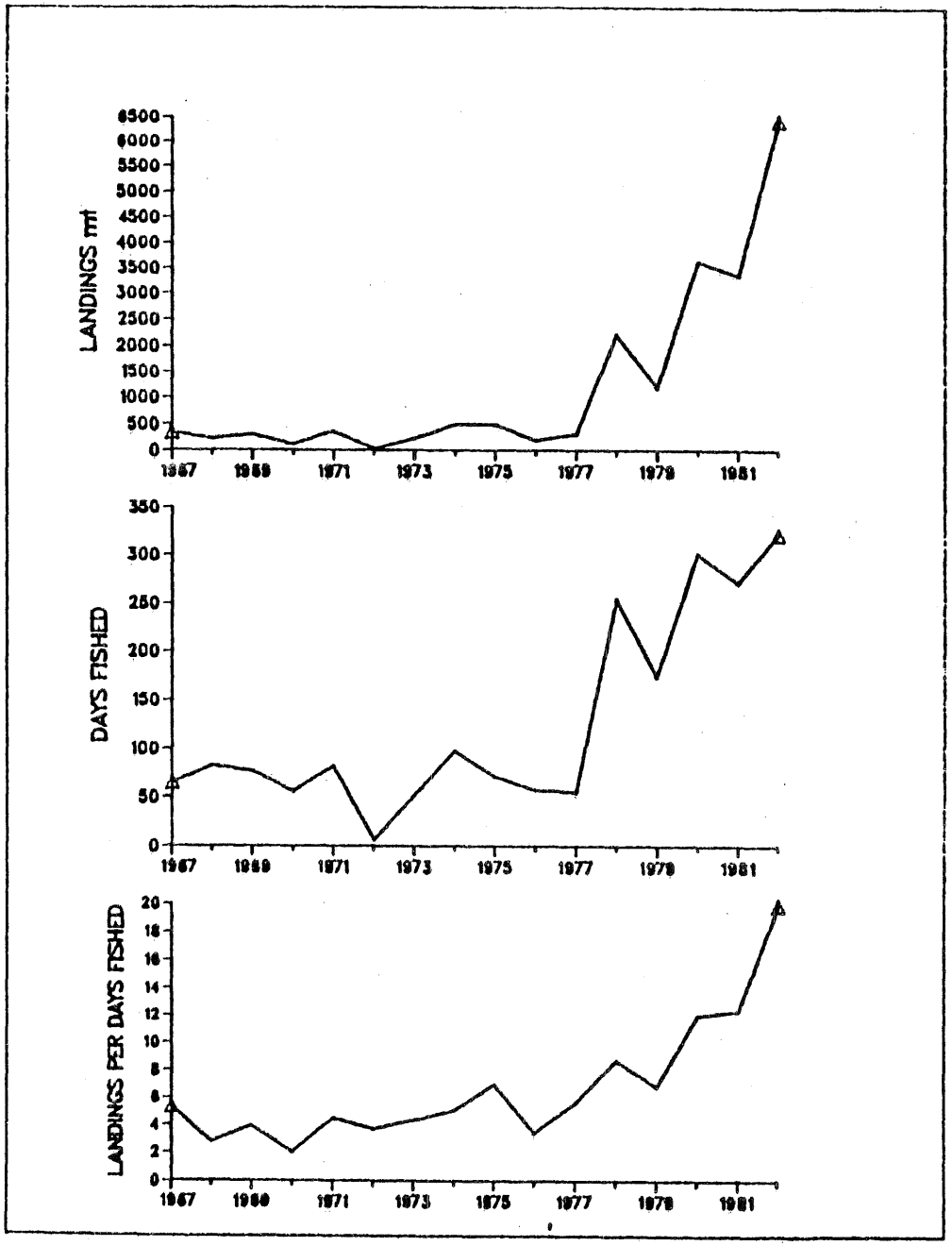


Figure 5. Landings, effort, and landing per effort for USA trawlers in which butterfish comprised 50% or more of the trip landings, 1967-1982.

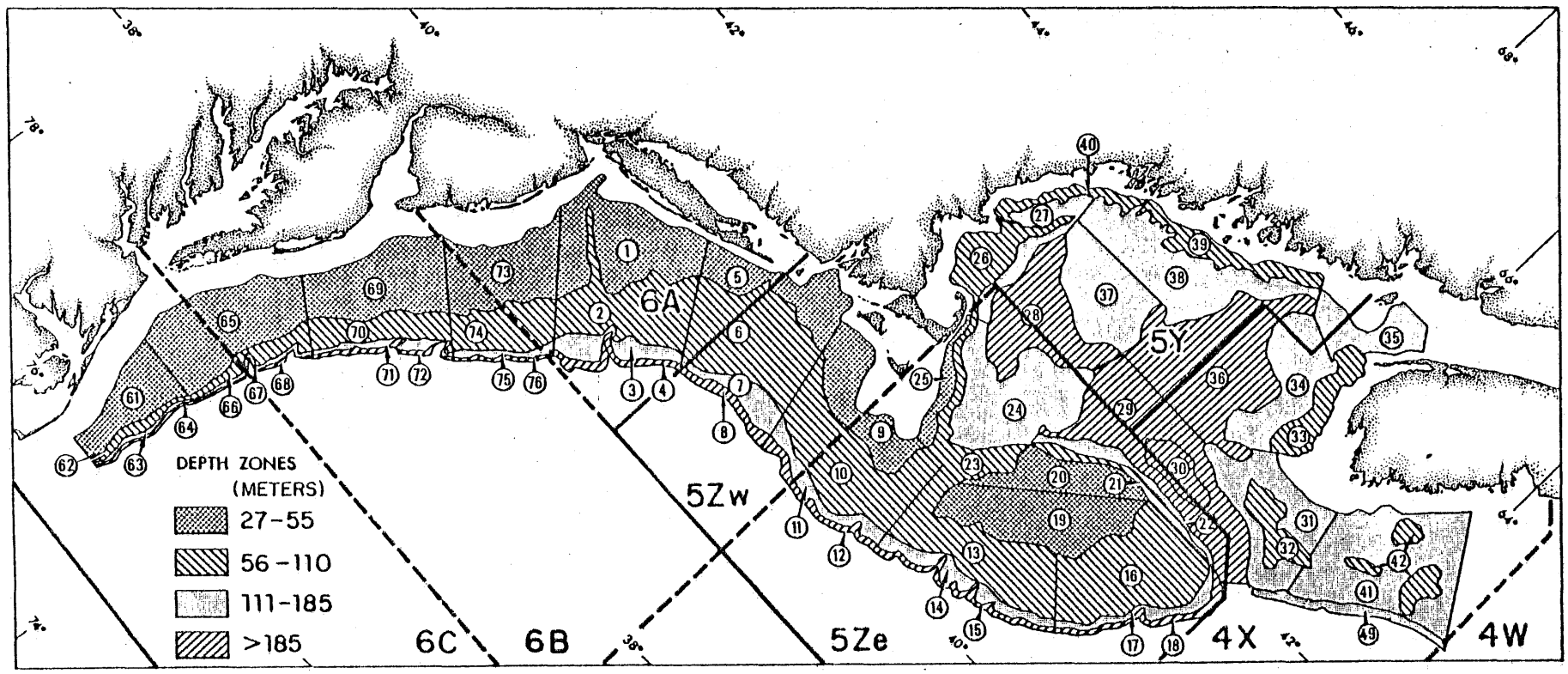
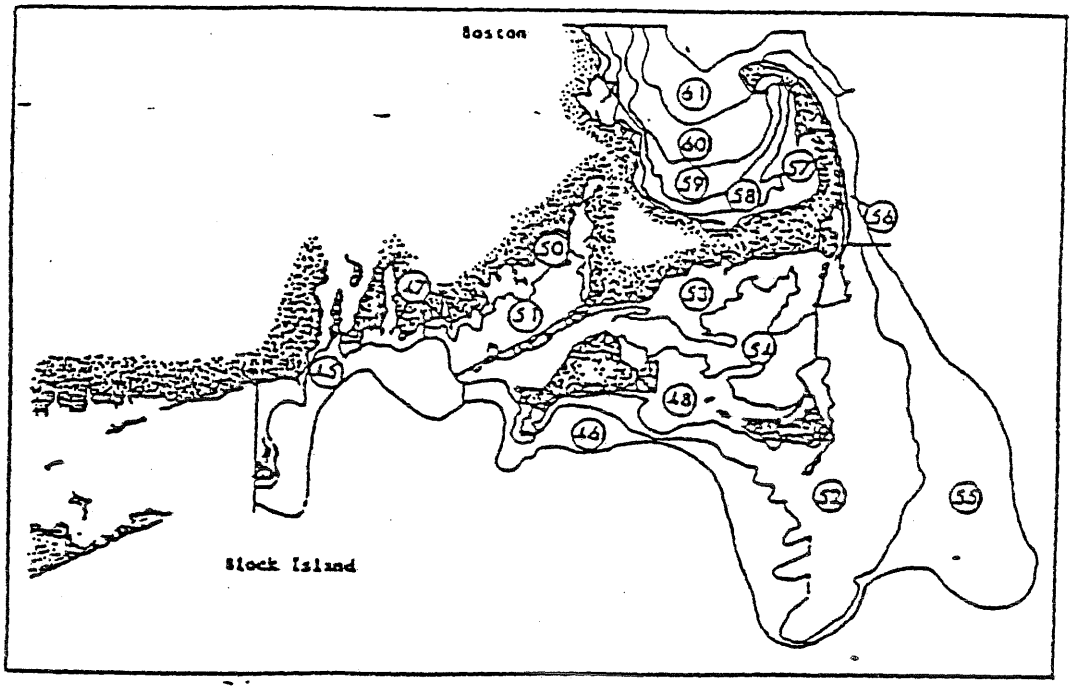


Figure 6. USA offshore bottom trawl survey sampling strata.

COASTAL STRATA

BLOCK ISLAND TO BOSTON



COASTAL STRATA

CAPE HATTERAS TO BLOCK ISLAND

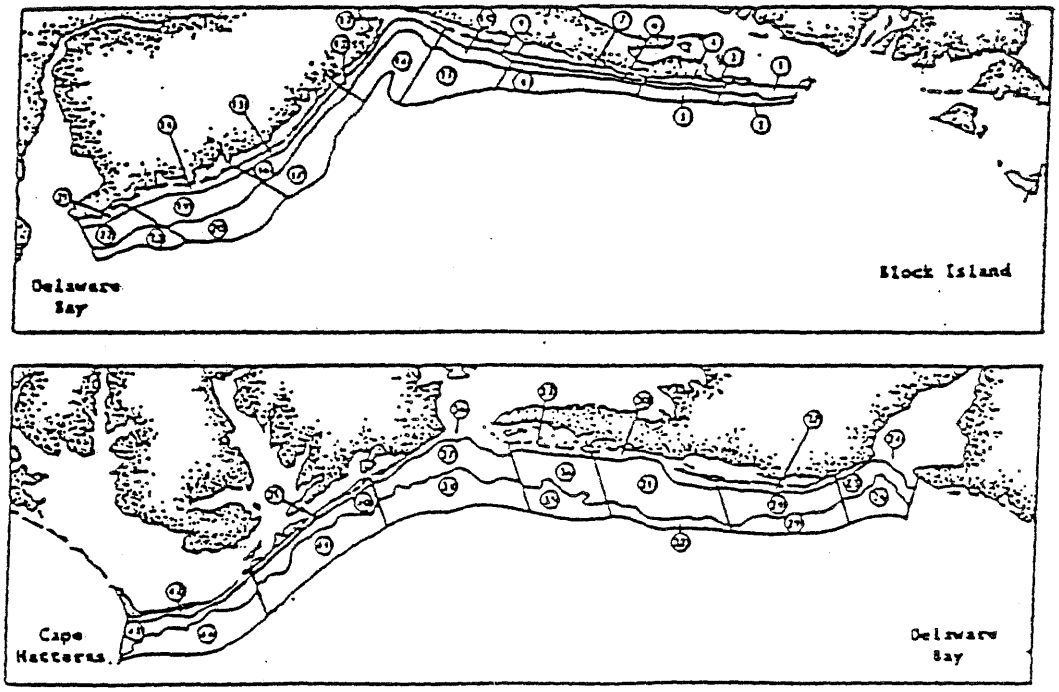


Figure 7. USA inshore bottom trawl survey sampling strata.

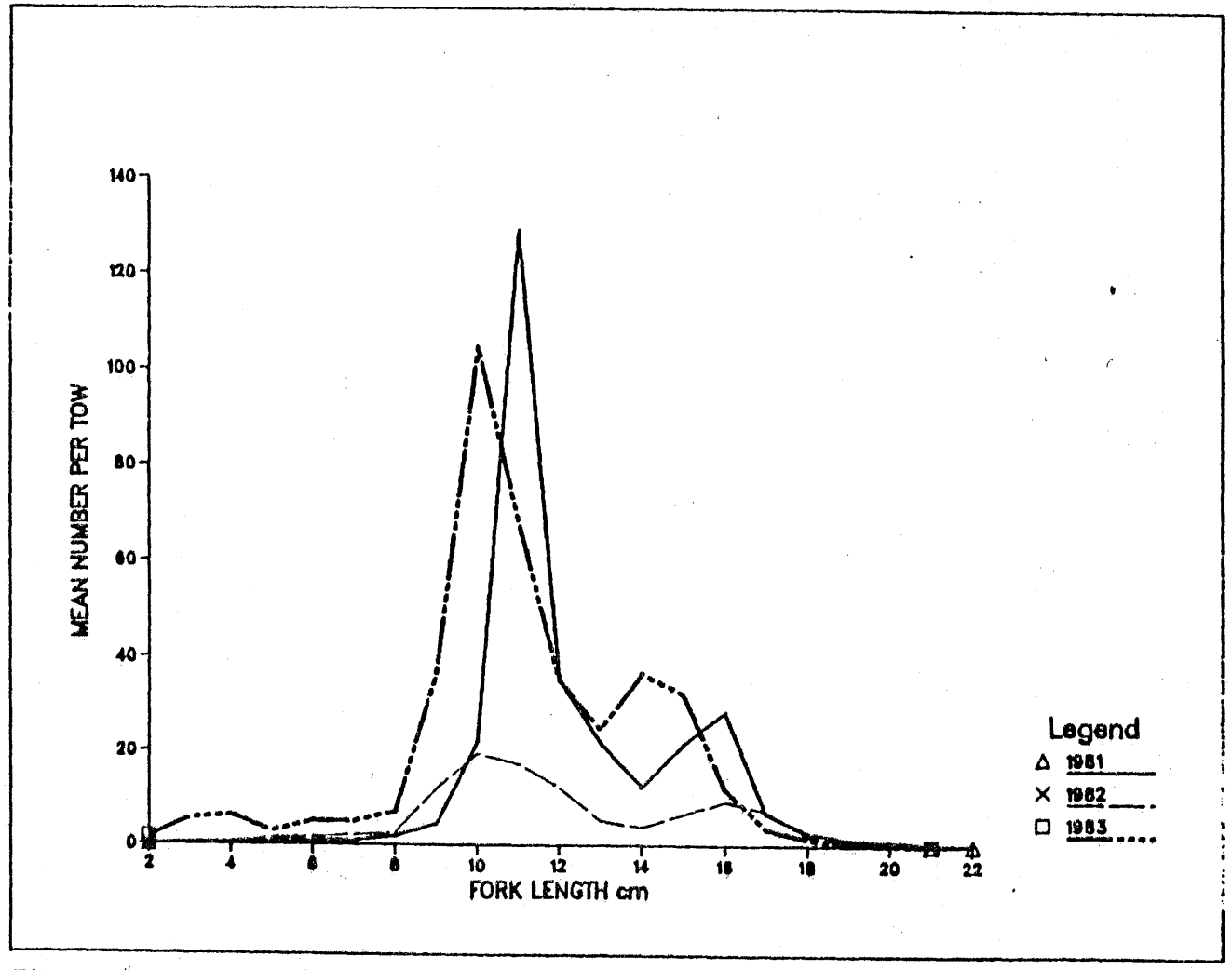


Figure 8. Mean number per tow at length for butterfish taken in 1981-1983 autumn bottom trawl surveys.

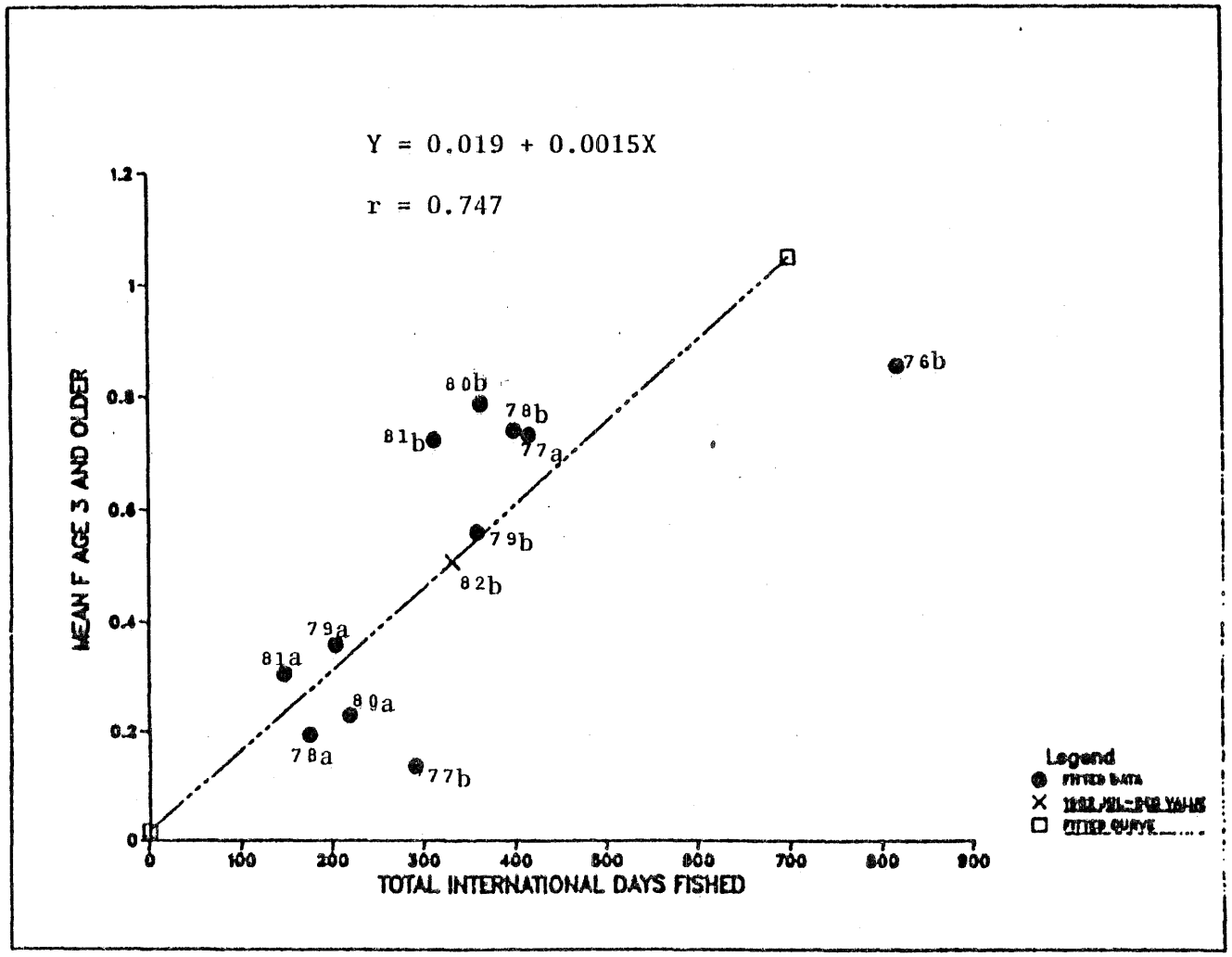


Figure 9. Relationship between total international effort (expressed as USA days fished) and mean fishing mortality rates (Coded ages 3 and older) by 6-month periods, Jan-Jun (a); Jul-Dec(b), for butterfish.

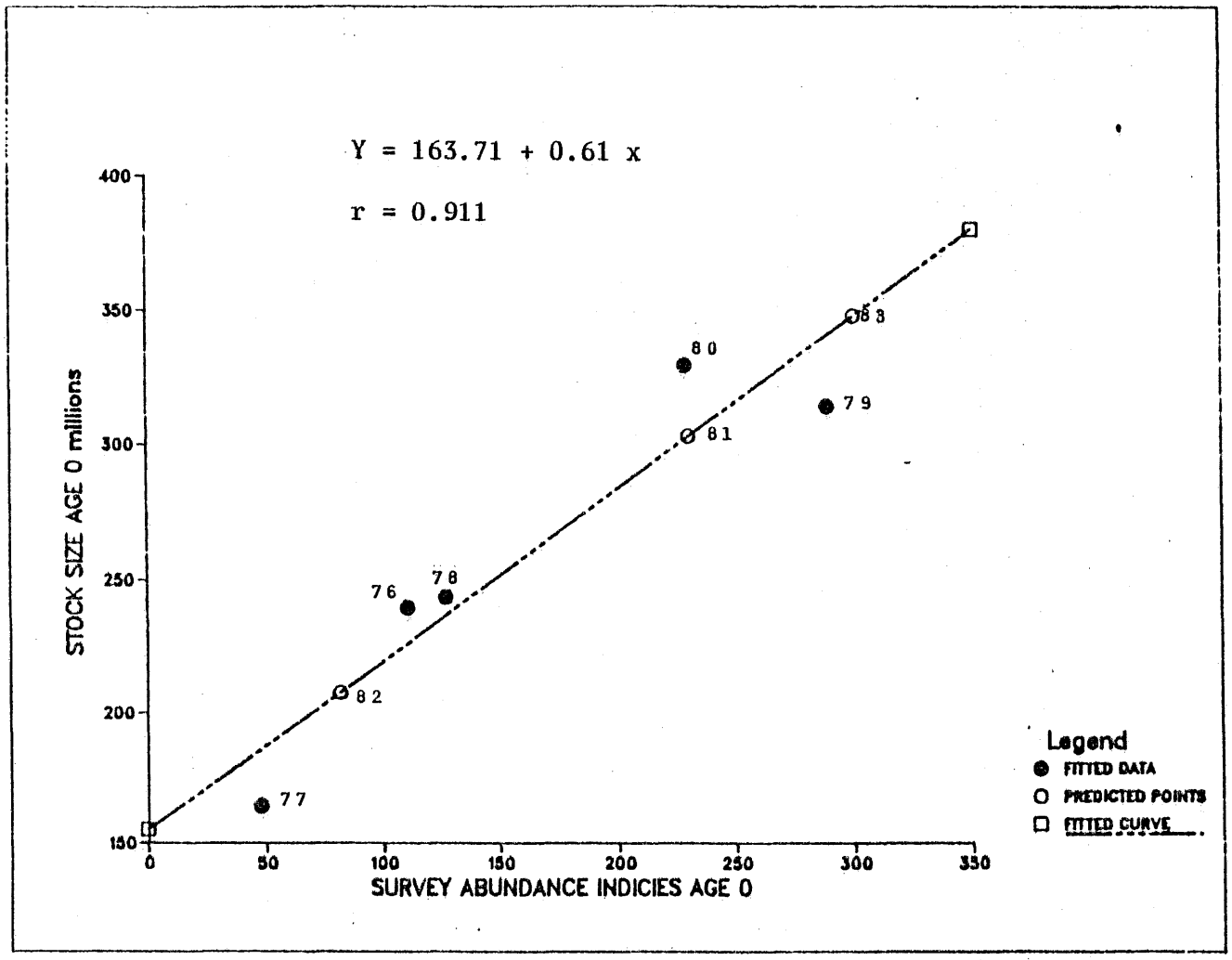


Figure 10. Relationship between NEFC autumn bottom trawl survey age 0 abundance indices (numbers per tow) and stock size estimates at age 0.

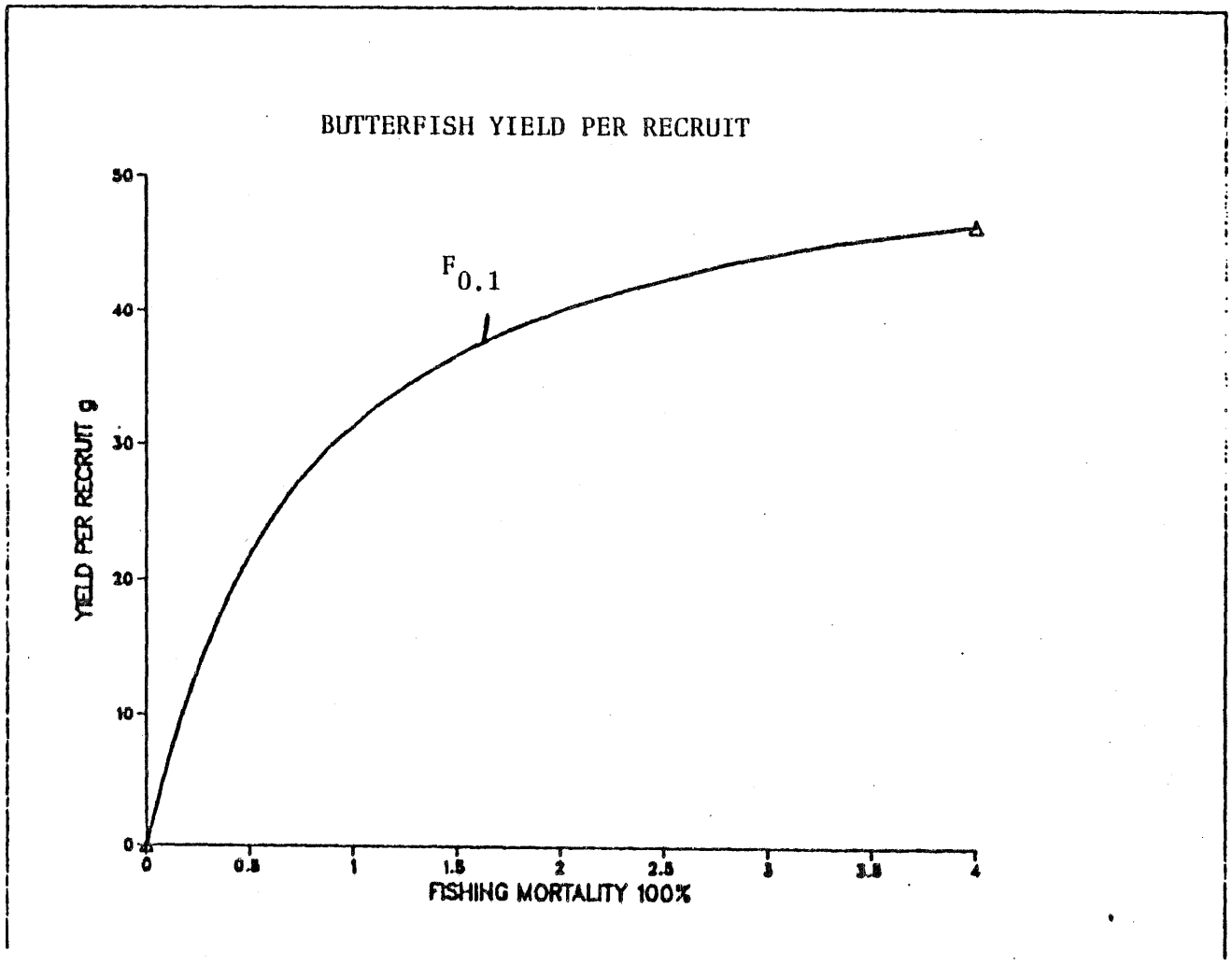


Figure 11. Yield per recruit for Northwest Atlantic butterfish.

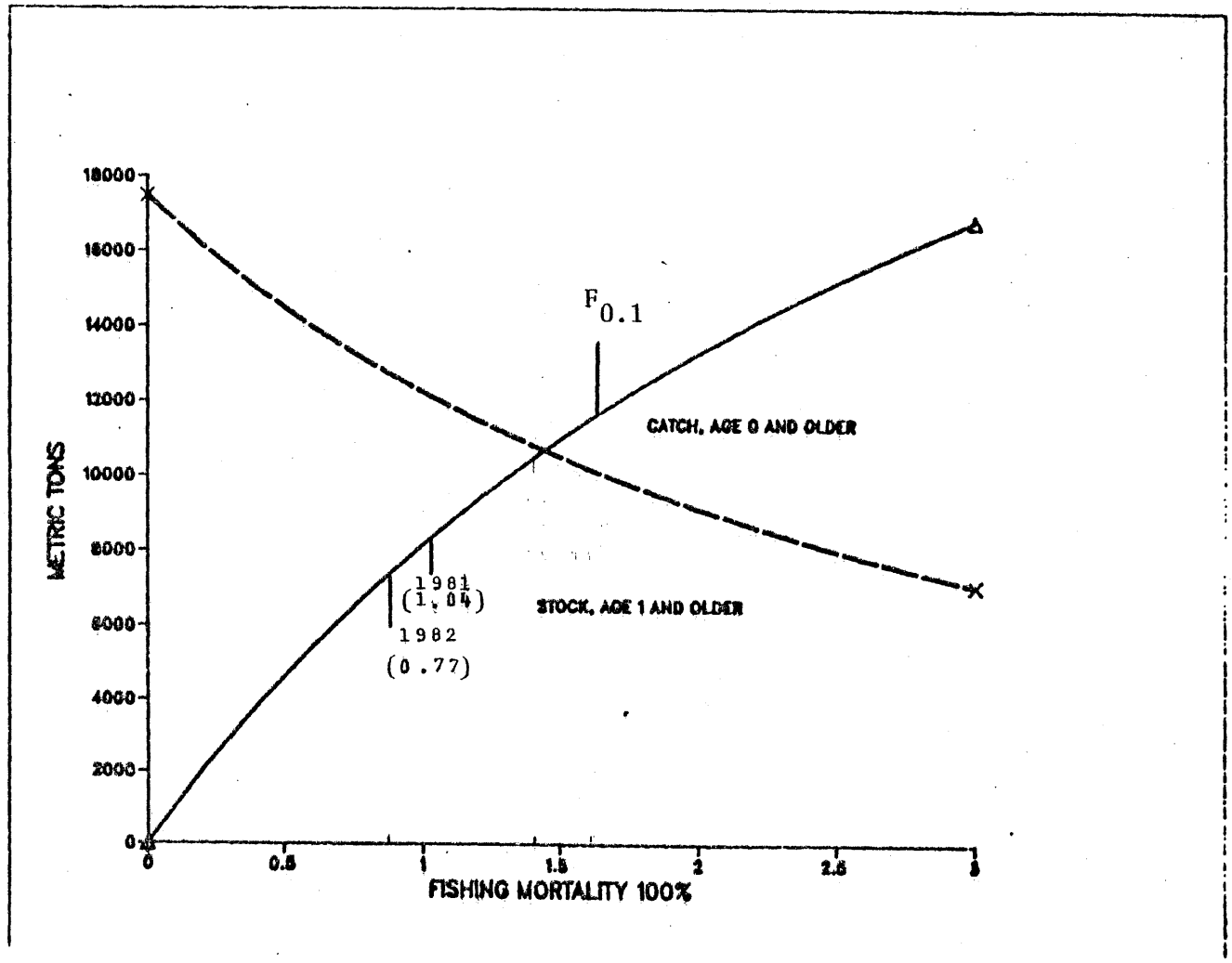


Figure 12. Projections of butterfish catch (age 0+) in 1984 and stock size in 1985 (age 1+).