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Assessment of Black Sea Bass North of Cape Hatteras, North Carolina

by

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This report is a product of the 20th Northeast Regional Stock Assessment Workshop (20th SAW). Proceedings and products of the 20th SAW are scheduled to be documented and released in the following CRD's:

CRD 95-13 Assessment of the Georges Bank haddock stock for 1994. By L. O'Brien and R.W. Brown.

CRD 95-14 An examination of the influence of environmental conditions on spring survey catches of Atlantic mackerel. By J.K.T. Brodziak and S.-W. Ling.

CRD 95-15 A comparison of some biological reference points for fisheries management By J.K.T. Brodziak and W.J. Overholtz.

CRD 95-16 Assessment for sea scallop in Mid-Atlantic and Georges Bank. By H.-L. Lai, P. Rago, S. Wigley, L.C. Hendrickson, and J. Idoine.

CRD 95-17 Assessment of black sea bass north of Cape Hatteras, North Carolina. By G.R. Shepherd and M.C. Lambert.

CRD 95-18 Report of the 20th Northeast Regional Stock Assessment Workshop (20th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments.

CRD 95-19 Report of the 20th Northeast Regional Stock Assessment Workshop (20th SAW): SAW Public Review Workshop.

Introduction

Black sea bass (*Centropristis striata*) is a demersal species inhabiting the continental shelf from Cape Cod, MA to southern Florida (Kendall and Mercer 1982). The species has been divided into two stock units, north and south of Cape Hatteras, NC (Mercer 1978), although there is some evidence of heterogeneity among the areas comprising the northern stock (Shepherd 1991). The northern stock undergoes seasonal migratory movements, moving northward and inshore to coastal waters during spring, and moving offshore and south to the edge of the continental shelf during the late autumn. Spawning occurs from May to August, with the season varying latitudinally. Juveniles inhabit coastal and estuarine areas and most are believed to participate in the seasonal offshore migration during the fall (Able *et al.* 1995).

Sea bass are protogynous hermaphrodites, transforming from females to males between the ages of 2 to 5 (Lavenda 1949, Mercer 1978). Sexual maturity occurs at age 2 for males and females. Male sea bass reach a maximum length of 60 cm and a maximum age of 15 years.

Black sea bass fisheries in the Exclusive Economic Zone (EEZ) were originally to be managed under a summer flounder-scup-black sea bass plan implemented by the Mid-Atlantic Fishery Management Council. However, summer flounder management was initiated first and a black sea bass plan was not begun until 1993. The results of that initiative are currently in the process of implementation. The proposed plan would institute a number of management measures in the first year of the management program including a minimum fish size, gear restrictions for otter trawl and pot fishermen, and a moratorium on commercial entrants. The plan calls for further restrictions beginning in year 3 of the management program, which could include commercial quotas and recreational possession limits. In addition, several states (MA, RI, NY, CT, NJ) have historically had 8" minimum size limits (12" in MA) on black sea bass.

The Fishery

Commercial Landings

Commercial landings north of Cape Hatteras fluctuated around 2,600 mt prior to 1948, at which point landings increased to 6,900 mt (NEFSC 1993). Landings peaked at 9,900 mt in 1952, declined steadily to 600 mt in 1971, then increased to 2,400 mt in 1977 (Table 1). Between 1983 and 1993, commercial landings ranged from 1,272 to 1,965 mt. Distant water fleet landings ranged from 4 to 41 mt between 1978 and 1987 and have been non-existent since 1988 (Table 1).

The predominate gear types in the commercial fishery are otter trawls which accounted for 25 to 76% of the landings since 1983 (an average of 51%) and fish pots which accounted for 17 to 62% (average of 34%) (Table 2). Hand lines accounted for 3 to 11% of the commercial landings (average 6%), with minor contributions from lobster pots, floating trap nets, and pound nets.

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The majority of landings are from fisheries in the EEZ, with an average between 1983 and 1993 of 85% (Table 2). The states of New Jersey and Virginia account for the majority of the landings with an average of 27% and 24% of the commercial landings, respectively (Table 2). Among the remaining states, Massachusetts, Rhode Island, Maryland, and North Carolina account for 9 to 11% each.

The otter trawl landings are primarily the result of by-catch in the summer flounder and squid fisheries (Shepherd and Terceiro 1994). The bulk of these fisheries occur during the winter months along the edge of the continental shelf. The pot fishery, which occurs in coastal waters from April to November, is directed towards black sea bass (Eklund and Targett 1991, Shepherd and Terceiro 1994).

Commercial Discards

The NEFSC sea sampling program has collected information on landings and discards in the commercial fishery on a regular basis from 1989 to 1993. Between 31 and 63 otter trawl trips per year were sampled in which sea bass were landed or discarded (Table 3). The reason for discarding was generally that fish were undersized relative to state regulations or marketability considerations.

An initial examination of sea sampling data was made to evaluate the effects of year, quarter, and area on the discard rate in the otter trawl fishery using analysis of variance. Quarter and area categories were statistically significant, although there was not a significant year effect. The first quarter in the southern areas (divisions 62 and 63) had the highest discard rate, consistent with our knowledge of the fishery.

Despite the statistical differences between area and quarter, there were not sufficient samples from which to calculate discards on a quarterly, area basis. Therefore, the data were pooled into half-year periods (January - June, July - December) across all areas for the purpose of discard estimations. Ratios of discards to landings for the period 1989-1993 were multiplied by otter trawl landings in the weighout data base on a half-year basis (Table 4). The discard rate for the second half of 1992 (47.7%) estimated from a single trip was judged anomalous and was replaced by an average of the rates for the second half of 1991 and 1993. To reflect discards in components of the fishery not included in the weighout data base (general canvas and North Carolina), the estimate of discard (by half year) was raised by the ratio of otter trawl commercial landings (by half year) to weighout landings. For 1984-1988, the average ratio of discard to landings from the period 1989-1991 was applied on a half-year basis. A discard mortality of 100% in the trawl fishery was assumed (Rogers *et al.* 1986).

Estimates of discards in the pot fishery were developed in a similar fashion. Although the slat spacing in fish pots allows the escapement of most small black sea bass, individuals states have minimum size regulations which impose further requirements for discarding undersized fish. Sea sampling data were available from 9 trips in 1989 in New Jersey (5) and Maryland (4). In the samples from Maryland, which were not constrained by a state size limit, the discarding of sea bass from pots was 0 in 3 of 4 trips. Samples from the New Jersey pot fishery, which had an 8" size limit, had an average discard-to-landings ratio of 12%. Sea sampling trips from inshore sea bass fisheries in Massachusetts indicate that survival approaches 100% (P. Caruso, MADMF, pers. comm.). Since most of the sea bass fisheries in southern New England are pursued in shallow water, a negligible discard mortality from pot fisheries in this region was assumed and no estimation of losses was provided. States south of New Jersey have not had a size limit on black sea bass and were assumed to have a limited discard such as that sampled from Maryland. The remaining fishery in New Jersey accounts for the majority of total landings from pots. Therefore, the 12% discard-to-landings ratio was applied to the New Jersey pot fishery landings data on a half-year basis in the same manner as described for trawl fisheries. Since mortality in shallow water fish pots approached 0%, a discard mortality of 50% was assumed. Estimates of total commercial discards are shown in Table 5.

Recreational Landings

Black sea bass is an important recreational species, with the greatest proportion of catches taken in the Middle Atlantic states (New Jersey to Virginia). Estimates of catch in numbers were obtained from the NMFS Marine Recreational Fishery Statistics Survey (MRFSS) for 1979 to 1994. Estimates were available for three categories: type A - fish landed and available for sampling, type B1 - fish landed but not available for sampling, and type B2 - fish caught and released. Catch estimates for North Carolina north of Cape Hatteras were determined from the total catch in number for North Carolina minus the percentage of North Carolina catch south of Cape Hatteras as estimated by Vaughan *et al.* (1995). Catch estimates in number for 1984-1994, the period covered by this assessment, are presented in Table 6. Landings ranged from 1.9 million fish in 1984 to 21.7 million fish in 1986. Recent landings have been between 3 and 5 million fish.

The estimated recreational landings (types A and B1) in weight during 1984-1994 ranged from 667 mt to 5,622 mt (Table 7) and averaged 1,721 mt per year. Recreational landings since 1983 have averaged 44% of the total landings by weight.

Recreational Discard

The estimated recreational discard (type B2) in number during 1984-1993 ranged from 1.59 million in 1984 to 7.11 million in 1986 (Table 6). Mortality of black sea bass recreational discards has been reported in the literature as 5% (Bugley and Shepherd 1991) in a shallow water fishery and 27% (Rogers *et al.* 1986) in deeper water. Since most of the recreational catch occurs in the EEZ, a 25% mortality was assumed for this assessment. Based on that rate, discard mortality in number ranged from 318,000 in 1984 to 1,422,800 in 1986 (Table 6). Total discards by weight (Table 7) were calculated from the mean weight at age of discards (see section on age composition).

Total Catch

Estimates of total catch of black sea bass are given in Table 7. The total catch during this period varied from a high of 7,823 mt in 1986 (driven primarily by a high recreational component) to a low of 2,863 mt in 1992. Other than 1986, the total catch has been relatively constant (2,900 - 3,600 mt) for the last ten years.

Sampling Intensity

Length samples of black sea bass were available from both commercial and recreational landings. In the commercial fishery, annual sampling intensity varied from 100 lengths per 40 mt to 100 lengths per 412 mt (Table 8). In all years except 1993, sampling exceeded the informal criterion of 100 lengths per 200 mt.

In the recreational fishery, sampling intensity varied from 100 lengths per 37 mt to 100 lengths per 165 mt (Table 9). In all years, sampling exceeded the minimum requirements.

Commercial Age Composition

Numbers at age were estimated for 1984-1993 for commercial landings and discards (Table 10). Numbers at length for the commercial landings were determined from the length frequencies collected by market categories applied to total landings per market category (Figure 2). The length frequency samples were assumed to be representative of the total landings, and were expanded to unsampled landings (general canvas data and unclassified landings). The summarized length frequencies by half-year periods were partitioned into age categories using age-length keys derived from NEFSC survey catches of black sea bass. Age-length keys from spring surveys were applied to numbers from the first half of the year, while age-length keys from autumn surveys were applied to numbers at length from the second half of the year. To provide ages in the age-length keys for fish greater than 42 cm, age data from all surveys were pooled into annual keys. This pooling applied to most fish older than age 7.

Discard length frequency information from sea sampling in the trawl fishery was collected from a limited number of tows per year since 1989. The first quarter of 1989 provided the only period with a sample size large enough to characterize the length frequency of discards versus landings in the otter trawl fishery (Figure 3). Additional discard length data were collected from the pot fishery in the Mid-Atlantic Bight in 1989 and 1994 and in coastal Massachusetts in 1993 (Table 11, Figure 4).

Discards at age were estimated using the available length frequency data and NEFSC survey age data. The available discard length samples, although not adequate to describe total discard length frequencies, indicated the range of sizes present in the discards. The application of NEFSC spring 1989 age data length keys to the 1989 first quarter discard lengths indicated that discards ranged in age from 1 to 4, with 92.2% ages 1 and 2 by weight.

The discard numbers at age were calculated for ages 1 and 2 in the first half of the year and 0 and 1 in the second half, assuming the first quarter discards also reflected the length distribution of the previous quarter. The ratio of ages 1 to 2 by weight was calculated from the annual spring NEFSC survey data and the ratio of ages 0 to 1 from the annual autumn survey data (Table 12). These ratios were applied to the discard estimates for each half-year period. Discard weights at age were converted to numbers using the mean weight at age from the survey data. Survey weights at age were calculated from the lengths at age and a length-weight equation developed from the corresponding survey period (Table 19).

Discards at age in the pot fishery were estimated in a similar fashion. Survey age-length keys applied to available length frequency samples in 1989 and 1994 as well as aged samples from the Massachusetts pot fishery (Table 11, Caruso 1995) indicated that the age composition of discards in the pot catches was primarily ages 2 in the spring fishery and age 1 in the autumn fishery. NEFSC survey weights at age were used to convert the weight of age 1 discards in the autumn and age 2 discards in the spring to numbers .

The results (Table 10) indicate periodic pulses of high juvenile discards, but no discernable trends. Although the available sea sampling data are probably adequate to indicate the general composition of the discards, the method chosen relies heavily on the NEFSC survey data. The resulting discards at age are estimated with a high degree of uncertainty.

Recreational Age Composition

NEFSC age-length keys for spring and autumn were applied to the recreational length frequencies (Figure 5) for the corresponding half-year periods. The numbers at age from the recreational landings are presented in Table 13. The weights at age were determined using the annual length frequencies by age and the NEFSC length-weight equations. Recreational landings were dominated by ages 1-3. Young-of-the-year fish were generally absent from the landings. The large landings in 1986 were dominated by the 1985 year class.

Recreational discard length data were derived from sea bass discards in the New York party boat fishery from 1992-1994 (Figure 6). The maximum discard size was 25 cm and discarded fish less than 15 cm, which accounted for 8% of the total number sampled, were not included in the analysis. NEFSC autumn survey data for fish between 15 and 25 cm were used to determine the age composition of the discards. Since the autumn survey data are occasionally dominated by fish 7-14 cm (age 0), the inclusion of this size range in the discard estimates would be biased toward age 0 fish, which have a higher selection by survey trawl gear than hook and line gear. Therefore, the discard size range was limited to 15-25 cm. The proportion at age for 15-25 cm fish in the NEFSC age length keys was estimated for spring and autumn. The proportions at age were applied to the seasonal (January - June, July - December) estimates of the B2 catch. Mean weights at age from the NEFSC data were used to calculate total weight of the recreational discards. The discards as calculated were ages 1-3 and were dominated by age 1 fish (Table 13).

Total Age Composition

The total catch at age matrix is the sum of commercial landings, commercial discards, recreational landings and recreational discards (Table 14). The age composition of the catch has been dominated by ages 1-3. Age 1 fish in the catch-at-age matrix account for 14.3% of the total, while age 2 fish account for 42.1%. Fish greater than age 4 comprise only 2.2% of the total catch.

Stock Abundance and Biomass Indices

Commercial LPUE

A general linear model (GLM, SAS 1985) of commercial otter trawl landings per unit effort (LPUE) was used to develop a standardized index of black sea bass. The general methods for the GLM were presented in SAW 9 (NEFC Ref. Doc. 89-08). Landings per day fished were calculated for trips in which black sea bass comprised >25% of the landed weight. Due to the bycatch nature of the fishery, higher % per trip as a measure of directedness results in a significant loss of data. The indices covered the period 1978-1993. The GLM included the effects of year, tonnage class, two-digit statistical area, and quarter, with 1993, tonnage class 3, area 63, and quarter 1 as the standard cell. The model explained 26% of the variance. The year coefficients were re-transformed adjusting for bias using 1/2 of the model mean square error term. The re-transformed year values provided an index of abundance.

The LPUE indices for 1978-1993, presented in Figure 7, indicate a reduced level of LPUE since the 1980s. The levels since 1991 are the lowest in the time series.

Recreational LPUE

A general linear model (SAS 1985) was also used to analyze the variation in MRFSS intercept LPUE for all intercepts coastwide and to produce a standardized index of abundance based on year category regression coefficients. Effort was considered all trips which landed black sea bass or in which sea bass was the primary or secondary species sought. The coefficients in the model included year, sub-region, mode, and area, with the standard cell being the 1993 party-charter boat LPUE from the offshore Mid-Atlantic area. The model explained 12% of the total variance. The year coefficients were retransformed as described for commercial LPUE and provided an index of abundance. In addition, a subset of the data for the Mid-Atlantic offshore party-charter boats was evaluated.

The LPUE indices show a relatively steady pattern since 1984 (Figure 8). In comparison, the subset of indices from the Mid-Atlantic has actually risen over the last several years. This increase may be a function of changes in recreational fishing practices in the last decade. There has been a substantial increase in the number of artificial reefs deployed along the Mid-Atlantic coast which are well known to the party boat fleets. It is conceivable that since these reefs provide good habitat for sea bass they also aggregate the population. This aggregating effect would tend to increase the relative efficiency of the party boat fleet's ability to target black sea bass and consequently increase the catch per angler per trip.

Research Vessel Indices

Indices of black sea bass abundance and biomass were calculated from catch-per-tow data from fishery-independent surveys conducted by the NEFSC, Massachusetts Division of Marine Fisheries (MADMF), Rhode Island Division of Fish, Wildlife, and Estuarine Resources (RIDFW), and the Virginia Institute of Marine Science (VIMS)

NEFSC spring survey

Long-term trends in black sea bass abundance were derived from a stratified random bottom trawl survey conducted between Cape Hatteras,NC and Nova Scotia since 1963 (Clark 1978). Prior to 1972, the survey was not conducted on inshore strata. The strata area defined for black sea bass extends from Cape Cod to Cape Hatteras and includes inshore and offshore strata. During the spring period, black sea bass tend to be congregated offshore along the edge of the continental shelf (Shepherd and Terceiro 1994). Total indices show a overall reduction since a period in the mid 1970's (Figure 9). Index values dropped from values of 7.151 in 1977 to 0.253 in 1994. The index in 1994 is the lowest since 1984. Age composition data is available since 1984. The spring survey catches fish age 1 to 10 (Table 15), with age 1 fish averaging 6 cm. The age 2 index is large in 1986, corresponding to the high recreational landings during the same year. That year class does not remain at high levels as age 3 in 1987. There is no indication of any large pulses of juvenile recruitment during this period. There is, however, indication of poor recruitment in 1992 and 1993. The overall age composition has remained relatively stable over the 1984-1993 time period.

NEFSC autumn survey

The autumn survey covers the period 1972 to present. The strata defined for this survey are the same as the NEFSC spring survey. The indices peaked in 1977 but have since shown considerable annual variation (Figure 9). During the autumn survey period, the sea bass are distributed inshore in coastal and estuarine waters. The affinity of sea bass to habitat generally unsuitable for otter trawls may influence their availability to the survey gear, and subsequently cause significant annual variation.

Age data from the period 1984 to 1993 includes fish ages 0 to 7 (Table 15). Indices suggest above average recruitment during 1985 and 1986. Fish greater than age 3 are generally absent from the survey. The index for age 0 in 1993 also indicates a poor year class, as seen in the spring survey. The juvenile abundance for 1994 appears to be above average.

NEFSC winter survey

A winter trawl survey was initiated in February of 1992 using gear specifically designed to capture flatfish. The overall indices for 1992-1995 suggest that the gear modification is also effective in capturing black sea bass. With only four years of data it is difficult to determine any trends. The 1994 index is substantially lower than the previous years possibly due to a reduced sample size (Table 16). The 1994 survey included a large number of 15 minute tows rather than the standard 30 minute tows. Since the 15 minute tows were not included in the index, the 1994 sample size was less than previous years. No age data were available for 1995.

Mass Division of Marine Fisheries (MADMF) spring survey

The MADMF bottom trawl survey has been conducted within state waters since 1978. The strata used in analysis of black sea bass comprised the area south of Cape Cod and Buzzards Bay. The overall index has declined during the course of the survey to a recent low value of 0.09 in 1992 (Figure 10). Since the areas covered by this survey are black sea bass spawning grounds, immature fish (primarily age 1) are under-represented in the spring survey. Sea bass to age 9 have been collected in this survey, although ages 2, 3, and 4 tend to be the most dominant (Table 17). The survey indicated an above average index for two year olds in 1986, consistent with the peak in recreational landings. In the 1993 and 1994 indices at age, there was a conspicuous absence of age 2 sea bass.

Mass Division of Marine Fisheries autumn survey

The strata area evaluated from the autumn survey is the same as spring. The overall autumn index dropped steadily until 1989 and has remained at a low level (Figure 10). The fall index is dominated by young of the year sea bass, probably the result of spring/summer spawning in local waters (Table 17). Recruitment in 1993 was nearly absent, although the 1994 cohort appeared to be above average. The strong 1984 year class is evident in 1985 and 1986.

Rhode Island Division of Fish, Wildlife and Estuarine Resources

A standardized bottom trawl survey has been conducted in Narragansett Bay and state waters of Rhode Island Sound since 1979. An index of abundance for young of the year black sea bass was developed from the survey using the CPUE of fish less than 11 cm. The index shows a large year class in 1981 and a smaller recruitment pulse in 1984-1986 (Table 18). Recruitment indices have been low since 1987, with evidence of a particularly poor year class in 1993. The overall CPUE in number peaked in 1981 and 1986. The index has remained low since 1986.

Virginia Institute of Marine Science (VIMS)

Since 1978 VIMS has conducted a bottom trawl survey in the lower James River and Chesapeake Bay which captures young of the year black sea bass. Beginning in 1987, the survey expanded into higher salinity nursery areas of the Chesapeake Bay which increased the catch of juvenile sea bass. The results since 1987 are presented in Table 18. The indices suggest a year of poor recruitment in 1992, but improved recruitment levels in 1993.

Life History Parameters

Few studies have been conducted on the population dynamics of the northern stock of black sea bass. Mercer (1978) carried out the first extensive study describing the life history of sea bass, including growth, mortality, and maturity. Growth information in the form of age-length and length-weight models from available sources are summarized in Table 19. For the purposes of this assessment, a von Bertalanffy growth curve was developed from NEFSC survey mean-length-at-age data. Since 1993, NEFSC bottom trawl surveys have collected weights of individual fish. The length-weight information from spring and autumn surveys was used to develop seasonal coastwide length-weight equations as well as a combined season equation. The natural mortality rate (M) was assumed to be 0.2.

Reproduction in black sea bass was first analyzed by Lavenda (1949), who documented the presence of protogynous hermaphrodites, and then by Mercer (1978). Recently, O'Brien *et al.* (1993) developed maturity ogives for black sea bass from NEFSC survey data between 1985 and 1990. Information provided by Alexander (1981) and Caruso (1995) on maturity from coastal samples is likely biased by the presence of predominately mature fish in coastal waters for the purpose of spawning. The general lack of age 1 fish in spring coastal surveys suggests that not all immature fish make the return migration to spawning areas. The available information for length and age at maturity for the northern stock of black sea bass is summarized in Table 19.

Mortality and Stock Size Estimates

Virtual Population Analysis (VPA) and Tuning

A nonlinear least squares sequential population analysis available in the software ADAPT (Conser and Powers 1990, Gavaris 1988) was used to determine fishing mortality rate (F) and stock size estimates.

The initial step in running the ADAPT software was determination of the exploitation pattern in the terminal year. The selection-at-age data were provided from a separable analysis in the SVPA model of Pope and Shepherd (1982). A terminal F of 0.5 and a terminal S of 1.0 at age 4 provided the lowest final sum of squared residuals. The resulting selection pattern with full recruitment at age 4 was:

Age	1	2	3	4	5	6+
S	0.100	0.430	0.889	1.000	0.811	1.000

The assumption of a flat topped selection pattern was made. Since selection at age 3 was higher than at age 5, which was assumed equal to 1.0, age 3 was also assumed to have reached full recruitment. Therefore, the model was re-run using full recruitment at age 3. The results were:

Age	1	2	3	4	5	6+
S	0.115	0.490	1.000	1.000	0.811	1.000

The catch was dominated by fish less than age 5. Therefore, the initial VPA was run for ages 0-5, with older ages grouped into a 6+ group.

All the available indices were not appropriate as tuning indices, since they all did not reflect the full population abundance. The only indices used in the tuning process were the NEFSC spring survey indices for ages 1-6, since this survey provided the most complete coverage during the time of the year prior to migration into estuarine habitats. Spring survey indices were compared to stock size numbers at the beginning of the same year.

Stock sizes in 1994 were directly estimated for ages 1-5, while the age 6+ group was calculated from F's estimated in 1993 and the input partial recruitment pattern. Tuning indices were weighted using an iterative re-weighting scheme. For all years prior to 1993, backcalculated stock sizes for ages 3, 4, and 5 were used to estimate fishing mortality at the oldest age (5). The F at the age 6+ group was assumed equal to the F for age 5. The coefficients of variation for the stock size estimates ranged from 1.4 for age 1 to 0.69 for age 4 (Table 20). Although the estimates were imprecise, particularly at age 1, it estimated the trend corresponding with other indices of abundance.

Stock Size, Fishing Mortality, Recruitment, and Spawning Stock Biomass

The final run provided estimates of stock size for ages 1+, which remained relatively stable between 1984 and 1992 (average of 41.8 million fish). An above-average 1984 year class appeared as a pulse into 1986, but the high abundance did not appear at age 3 in 1987. Stock numbers dropped dramatically to an estimated 10.9 million fish at the beginning of 1994.

Average fishing mortality rates for fully recruited ages (3-6) were very high throughout the time period (1984-1993), being above 1.0 each year, and exceeded 1.9 in 1991-1992 (Figure 11). The estimated F declined during 1993 to 1.05.

Estimates of recruitment at age 1 averaged 20 million fish between 1984 and 1992 (Figure 12). Recruitment in 1993 (the 1992 year class) dropped to 2.5 million and to 1.6 million in 1994 (the 1993 year class). This resulted in a sharp decline in stock numbers in 1993 and 1994. The presence of an above-average year class in 1991 maintained the catch biomass at a relatively steady level through 1993. Due to the dominance of age 2 and 3 fish in the catch, good annual recruitment is necessary in maintaining recent catch levels.

The spawning stock biomass (SSB) estimates included spawning biomass of males and females and has remained relatively stable from 1984 to 1993, ranging from 2,150 mt to 4,554 mt (Figure 12). The SSB level in 1993 (3,115 mt) was the second highest in the ten year time series. The poor recruitment in 1992 and 1993 has not contributed fully to spawning stock biomass and full maturity of this year class would be expected to result in a sharp decline in SSB.

Precision of F and SSB Estimates

To evaluate the precision of the final VPA estimates, a bootstrap procedure with 500 iterations was used to generate distributions of the estimated 1993 fishing mortality rate and spawning stock biomass. The results in figures 13 and 14 depict the frequency of the F and SSB values and the probability that F is greater than a target value or that SSB is less than the targeted estimate.

The bias-corrected estimates of the coefficient of variation (CV) for stock number (Table 21) ranged from 58% at age 5 to 154% at age 1. The bootstrap estimate of fully-recruited F in the terminal year equaled 0.98. The bootstrap estimates indicate that there is a 90% probability that F in 1993 is greater than or equal to 0.67 (Figure 13) .

The bias-corrected estimate of SSB for 1993 was 2,773 mt, which was lower than the point estimate of 3,116 mt, and had an estimated CV of 34%. Bootstrap estimates indicated that there was an 80% probability that the 1993 spawning stock biomass was between 2,400 mt and 4,700 mt (Figure 14).

Biological Reference Points

Yield per Recruit

Estimates of biological reference points were derived from the Thompson and Bell (1934) model. Recent work by Shepherd and Idoine (1993) indicated that the protogynous life history of black sea bass does not impact the calculation of yield-per-recruit reference points, because both males and females are included in the yield estimates. The spawning stock biomass per recruit estimates for females can be profoundly different with inappropriate model specification. However, in this analysis, only total spawning stock biomass was considered and included both mature male and female fish which avoids the problem of accounting for sexual transformations. The input parameters and results of the Thompson and Bell model are presented in Table 22. The fishing mortality pattern was determined using the geometric mean of the 1989-1992 backcalculated partial recruitment coefficients estimated from the final ADAPT run. The 1993 estimates were not included due to the imprecision of these estimates for the terminal year. The proportion of F and M prior to spawning was based on the seasonal pattern of catch, with the mid-point in the spawning season assumed to be mid-June. A maximum age of 15 was assumed, given a natural mortality of 0.2 and the relationship of the oldest age equal to 3/M. The proportion mature was based on the maturity information developed by O'Brien *et al.* (1993). Average stock weights were obtained from NEFSC survey data, while the catch weights were based on the total catch mean weights at age. The weights for older ages were from projections based on a growth curve developed from the NEFSC survey data.

The input parameters described resulted in an estimate of F_{max} of 0.29 and an estimate of $F_{0.1}$ of 0.18. These estimates differ from previously reported values due to changes in the growth data and the refinement of the exploitation pattern. There is little information available concerning the impact of fishing mortality on reproductive potential in an hermaphroditic species. Consequently no estimates were made of maximum spawning potential under different fishing mortalities.

Summary and Conclusion

The results of the virtual population analysis indicate that the northern stock of black sea bass is overfished. Despite the imprecision of the estimates, fishing mortality is much greater than the level required for maximum yield per recruit. Spawning stock biomass has remained steady over the last decade but will likely be reduced in the future due to very poor recruitment in 1992 and 1993.

The VPA results suggest that the population biomass has remained relatively stable over the past decade. This corresponds to the relatively stable commercial and recreational LPUE during the same time period. Survey indices have been relatively stable during the 1980's but shown an overall decline since the 1970's. Although there appears to be a reduction of F in 1993, the decade of elevated F levels may be associated with the poor recruitment apparent in 1992 and 1993.

The level of F indicated by the VPA is somewhat contradictory to the relatively stable landings and recreational LPUE indices. The behavior of black sea bass is very structure-oriented; thus it may be possible to maintain catch levels even with a declining stock if fishermen know the location of appropriate structure around which sea bass would congregate. On the other hand, this habitat preference may provide a refuge effect from mobile fishing gear, particularly for the larger fish.

There is the possibility that this habitat preference may result in a dome-shaped partial recruitment pattern rather than the assumed flat-topped pattern. This could produce a bias toward a higher estimate of fishing mortality rate. Given the relatively short time series of age data (10 years), it is currently not possible to develop historic estimates of F and stock size to improve the understanding of how the stock has withstood high levels of fishing mortalities.

There are several pieces of evidence that the stock is being overfished. The survey indices and landings are much reduced from historic levels. The VPA, despite the high degree of imprecision, suggests the level of F exceeds the biological reference point, and the level of F is substantiated by the elevated mortalities as determined from catch curve analyses.

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Table 1. Landings (mt) of black sea bass north of Cape Hatteras, NC, 1950-1994.

Year	Commercial	Foreign	Recreational
1950	5736		
1951	8361		
1952	9883		
1953	6521		
1954	5141		
1955	5131		
1956	5251		
1957	4320		
1958	5242		
1959	3655		
1960	3102		
1961	2483		
1962	3692		
1963	3798		
1964	3199		
1965	3604		
1966	1652		
1967	1302		
1968	1201		
1969	1199		
1970	1100		
1971	614		
1972	760		
1973	1161		
1974	1069		
1975	1885		
1976	1690		
1977	2424		
1978	2115	5	
1979	1875	41	560
1980	1252	14	1002
1981	1129	39	1062
1982	1177	21	4499
1983	1513	14	1967
1984	1965	18	667
1985	1551	33	1052
1986	1901	10	5622
1987	1890	4	901
1988	1879		1241
1989	1324		1509
1990	1588		1268
1991	1272		1887
1992	1364		1199
1993	1412		2031
1994			1306
Mean	2736	20	1736

Table 2. Proportion of black sea bass commercial landings by year, gear type, distance from shore and state for the area north of Cape Hatteras, NC.

	Gear Type				Distance from Shore	
Year	Otter Trawl	Pot	Handline	Other	% Landings ≤ 3 miles	% Landings > 3 miles (EEZ)
1983	67.7	22.8	4.7	4.8	17	83
1984	75.6	16.7	3.0	4.7	15	85
1985	66.9	17.0	7.0	9.1	19	81
1986	60.7	28.5	6.3	4.5	17	83
1987	61.5	32.6	3.5	2.4	12	88
1988	59.1	33.5	5.2	2.2	13	87
1989	51.9	39.4	6.6	2.1	15	85
1990	48.7	43.2	6.2	1.9	18	82
1991	24.6	61.9	10.7	2.8	18	82
1992	37.0	50.8	8.5	3.7	11	89
1993	61.8	33.3	2.3	2.6	9	91
Mean	51.2%	34.5%	5.8%	3.7%	15%	85%

State	% Landings 1983-1993
Maine	0 %
New Hampshire	0 %
Massachusetts	9 %
Rhode Island	10 %
Connecticut	1 %
New York	4 %
New Jersey	27 %
Delaware	4 %
Maryland	10 %
Virginia	24 %
North Carolina	11 %

Table 3. Number of sea sampling trips catching black sea bass by year, quarter, statistical area.

	Division	Quarter 1	2	3	4	Total
1989	51		1	1	1	3
	52		1		1	2
	53	2	9		3	14
	61	4	5		4	13
	62	5	2	6	1	14
	63	2				2
Total		13	18	7	10	48
1990	51					
	52		2			2
	53	2	4		2	8
	61	8	5		2	15
	62	3	7		3	13
	63	1				1
Total		14	18		7	39
1991	51				1	1
	52					
	53	4	5		3	12
	61	4	3		14	21
	62	5	3	3	4	25
	63				4	4
Total		9	11	3	26	49
1992	51	2				2
	52	2				2
	53	6	2		3	11
	61	14	3	1	3	21
	62	13	2	4	3	22
	63	4			1	5
Total		41	7	5	10	63
1993	51					
	52	1	1			2
	53	6	3		6	15
	61	6	2		2	10
	62	1			1	2
	63				2	2
Total		14	6		11	31

Table 4. Ratios of discards to landings, by half year period, from sea sampled otter trawl trips, 1989-1993.

Year [Half year]	Discard lbs	Kept lbs	Ratio
1989			
1	824	4648	0.177
2	167	4575	0.037
1990			
1	547	5477	0.100
2	71	564	0.126
1991			
1	64	3055	0.021
2	227	1397	0.179
1992			
1	1059	11651	0.091
2	average 1991 and 1993		0.094
1993			
1	247	2834	0.087
2	4	518	0.008

Table 5. Commercial discard estimates (mt) for trawl and pot fisheries, 1984 to 1993, assuming 100% by-catch mortality in trawl and 50% in pot fishery.

Year	Trawl	Pot	Total
1984	168.3	6.2	174.5
1985	119.8	6.2	126.0
1986	131.8	11.0	142.9
1987	131.8	9.0	140.9
1988	125.2	10.5	135.7
1989	93.6	12.0	105.6
1990	83.4	15.2	98.6
1991	32.0	23.1	55.1
1992	124.4	22.5	146.9
1993	55.6	13.1	68.7

Table 6. MRFSS black sea bass harvest (A + B1) and release (B2) estimates in number (000's adjusted to include North Carolina catch from north of Cape Hatteras).

Year	Harvest	Releases	% Releases	Discard Losses
1984	1881	1589	45.7	397
1985	3771	2701	41.7	675
1986	21747	7114	24.6	1778
1987	2936	2134	42.1	533
1988	2949	4966	62.7	1242
1989	4286	2175	33.6	544
1990	3920	5196	57.0	1299
1991	5237	5529	51.3	1382
1992	3557	4113	53.6	1028
1993	5540	2754	33.2	688
1994	3334	3632	52.0	908

Table 7. Catch (mt) of black sea bass from Maine to North Carolina (Note: Pot discards assume 50% discard mortality,trawl 100% discard mortality and recreational 25% discard mortality).

YEAR	Landings Commercial	Landings Recreational	Landings Foreign	Discards Recreational	Discards Commercial	Total Catch
1984	1,965	667	18	34	175	2,859
1985	1,551	1,052	33	66	126	2,828
1986	1,901	5,622	10	147	143	7,823
1987	1,890	901	4	66	141	3,002
1988	1,879	1,241		137	136	3,393
1989	1,324	1,509		69	106	3,008
1990	1,588	1,268		135	99	3,090
1991	1,272	1,887		143	55	3,357
1992	1,364	1,199		153	147	2,863
1993	1,412	2,031		96	69	3,608
Mean	1,615	1,738	16	91	120	3,583

Table 8. Summary of sampling intensity for black sea bass in the commercial fisheries, 1983-1994.

Year	No. of Samples	No. of Lengths	Weighout landings (mt)	Sampling intensity (mt/100 lengths)
1983	32	3219	1314	41
1984	36	3841	1519	40
1985	26	2509	1075	43
1986	31	2922	1508	52
1987	15	1545	1635	106
1988	13	1376	1424	103
1989	8	883	989	112
1990	11	1142	1190	104
1991	7	735	1022	139
1992	6	605	1148	190
1993	3	300	1236	412

Table 9. Summary of sampling intensity for black sea bass in the recreational fisheries, 1983-1994.

Year	No. of Lengths	Estimated Landings	Sampling intensity (mt/100 lengths)
1983	1196	1967	164
1984	953	667	70
1985	1887	1052	56
1986	3400	5622	165
1987	1087	901	83
1988	1058	1241	117
1989	4096	1509	37
1990	2739	1268	46
1991	2654	1887	71
1992	2560	1199	47
1993	1601	2031	127
1994	1559	1306	84

Table 10. Commercial landings and discard at age (00's) for black sea bass from Cape Cod to North Carolina, 1984-1993. Otter trawl discard assumes 100% mortality and pot/trap discard assumes 50% mortality.

Landings (00's)

Year	Age 0	1	2	3	4	5	6	7	8	9	10	Total
1984	0	2672	11912	28600	15921	1328	370	219	7	2	0	61031
1985	0	298	11266	17133	11766	1897	1070	375	183	43	20	44051
1986	0	2017	53434	10586	2015	215	171	18	55	5	0	68516
1987	0	0	20146	32424	4945	1396	218	79	0	0	0	59208
1988	0	3305	30802	31052	7565	1868	0	0	0	0	0	74592
1989	0	239	9569	12818	7565	1187	353	0	0	0	0	31731
1990	0	13	10727	35775	5791	767	0	0	0	0	0	53073
1991	0	654	32468	8610	3305	3525	63	0	0	0	0	48625
1992	0	20	31632	20946	4924	64	38	0	0	0	0	57624
1993	0	902	41450	14926	828	0	0	0	0	0	0	58106

Discards (00's)

Year	Otter Trawl Age 0	Otter Trawl Age 1	Otter Trawl Age 2	Otter Trawl Total	Pots Age 1	Pots Age 2	Pots Total
1984	663	8175	10981	19819	679	196	875
1985	16974	11593	7158	35725	744	173	917
1986	11803	8237	5222	25261	1503	241	1744
1987	1950	12147	7438	21536	610	346	956
1988	2831	11177	8074	22082	1906	183	2089
1989	2988	4168	7108	14264	1105	397	1502
1990	1153	9501	4100	14755	2157	17	2174
1991	1394	7416	511	9320	4515	445	4960
1992	5275	3915	2297	11487	2952	270	3223
1993	0	274	5696	5970	1654	76	1730

Table 11. Catch at age from the sampled catch of the Massachusetts pot fishery during spring/summer 1993.

Length (cm)	AGE 2	3	4	5	6	
20						
21	7					
22	18					
23	28					
24	37	4				
25	45	4				
26	57	7				
27	36	9				Discards
28	28	25				
29	10	26				
30	3	30				
31		42	2			Landed
32		55	3			
33		44	2			
34		50	2			
35		49				
36		39	4			
37		25	8			
38		24	7			
39		9	4			
40		5	5	1		
41		1	4	1		
42			5	1		
43		1	5	1		
44			2	2		
45			1	2		
46			1	4	3	
47			1	4	1	
48				3	2	
49				2	1	
50				1	2	
51				1	1	

Source: P. Caruso, Massachusetts Division of Marine Fisheries

Table 12. Proportions of age 1 and age 2 fish by weight in black sea bass commercial discards.

	Spring		Autumn	
Year	age 1	age 2	age 0	age 1
1984	0.007	0.993	0.007	0.993
1985	0.082	0.918	0.180	0.820
1986	0.003	0.997	0.102	0.898
1987	0.003	0.997	0.038	0.962
1988	0.013	0.987	0.087	0.913
1989	0.010	0.990	0.083	0.917
1990	0.055	0.945	0.017	0.983
1991	0.082	0.918	0.074	0.926
1992	0.016	0.984	0.114	0.886
1993	0.000	1.000	0.000	1.000

Source: NEFSC spring and fall bottom trawl surveys.

Table 13. Recreational landings and discards at age (000's) for black sea bass from Cape Cod to North Carolina, 1984-1993. Discard mortality was assumed to be 25% mortality.

Landings (000's) — Age

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	6	418	582	745	64	7	17	1	1	1	0	1843
1985	8	509	1827	821	456	86	55	6	3	0	0	3771
1986	0	3221	13660	3537	750	218	220	18	71	22	38	21747
1987	0	143	1481	1085	91	22	91	2	2	0	15	2931
1988	0	294	1454	862	217	83	25	2	12	0	1	2949
1989	1	144	2527	1305	213	34	42	6	6	6	2	4285
1990	0	518	1507	1507	277	86	19	0	2	0	4	3920
1991	2	180	2918	1269	604	218	26	2	7	8	4	5237
1992	4	117	1803	1258	319	30	18	2	3	3	0	3557
1993	0	391	3474	1161	455	35	16	1	4	1	0	5539

Discards (000's) — Age

Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	0	375	19	3	0	0	0	0	0	0	0	397
1985	0	495	153	27	0	0	0	0	0	0	0	675
1986	0	1484	294	0	0	0	0	0	0	0	0	1779
1987	0	232	294	7	0	0	0	0	0	0	0	534
1988	0	1012	210	19	0	0	0	0	0	0	0	1241
1989	0	195	342	7	0	0	0	0	0	0	0	544
1990	0	755	522	22	0	0	0	0	0	0	0	1299
1991	6	548	761	15	0	0	0	0	0	0	0	1324
1992	0	320	656	52	0	0	0	0	0	0	0	1028
1993	0	270	373	45	0	0	0	0	0	0	0	688

Table 14. Total catch at age (000's) and mean weight at age (kg) for black sea bass from Cape Cod to North Carolina, 1984-1993.

	Age											
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	72	1945	2910	3608	1656	140	54	23	1	2		10412
1985	1705	2267	3840	2561	1633	276	162	44	21	4	2	12515
1986	1180	5881	19844	4596	951	233	237	19	76	23	38	33078
1987	195	1651	4568	4334	586	161	113	1	2	0	15	11635
1988	283	2945	5570	3986	974	269	25	2	12	0	1	14067
1989	300	890	4576	2593	793	153	77	6	6	6	2	9401
1990	115	2439	3514	5107	608	162	19	1	2		4	11971
1991	142	1987	7021	2144	1096	571	32	2	7	8	4	13014
1992	532	1126	5879	3404	579	36	22	2	3	3		11586
1993	0	945	8569	2699	538	35	16	1	4	1		12808
%>0		96.78										
%>1			81.07									
%>2				33.88								
%>3					8.94							
%>4						2.24						

Mean wt at age (kg)

	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
1984	0.006	0.077	0.166	0.293	0.470	0.852	1.214	0.853	1.290	1.722	
1985	0.003	0.049	0.154	0.264	0.519	0.849	1.256	0.864	1.549	1.949	2.377
1986	0.003	0.073	0.185	0.394	0.663	0.997	1.333	1.199	1.536	1.830	2.369
1987	0.007	0.073	0.176	0.334	0.534	0.782	1.329	1.113	1.370		2.444
1988	0.006	0.062	0.192	0.320	0.413	0.518	1.164	1.184	1.265	1.878	2.223
1989	0.003	0.042	0.184	0.342	0.474	0.741	1.055	1.334	1.500	1.906	2.127
1990	0.004	0.052	0.176	0.323	0.527	0.692	1.179	1.128	1.529		2.460
1991	0.014	0.049	0.161	0.308	0.508	0.631	1.347	1.213	1.571	2.337	2.237
1992	0.004	0.067	0.190	0.308	0.545	0.994	1.284	1.176	1.290	1.898	
1993		0.095	0.201	0.321	0.584	0.927	1.383	1.253	1.469		

Table 15. Mean catch per tow (numbers) at age for NEFSC spring and autumn research vessel surveys, 1983-1993.

Spring

Year	Age 0	1	2	3	4	5	6	7	8	9	10	Total
1984		0.01	0.07	0.07	0.05	0.01	0.01					0.23
1985		0.08	0.08	0.13	0.12	0.02	0.01					0.45
1986		0.15	1.18	0.50	0.06							1.91
1987		0.02	0.67	0.35	0.06	0.04	0.03					1.17
1988		0.39	0.70	0.62	0.13	0.08	0.02		0.01			1.96
1989		0.20	0.41	0.10	0.03		0.01		0.01			0.76
1990		0.35	0.20	0.23	0.03	0.01						0.84
1991		0.63	0.21	0.06	0.03							0.94
1992		0.32	0.56	0.64	0.10	0.01					0.01	1.64
1993		0.00	0.80	0.56	0.03							1.40
1994		0.01	0.03	0.14	0.06	0.01						0.25

Autumn

Year	Age 0	1	2	3	4	5	6	7	8	9	10	Total
1983	0.54	0.06	0.14	0.05	0.02							0.80
1984	0.21	2.07	0.07	0.01	0.00							2.38
1985	1.96	0.49	0.11	0.03	0.02	0.01						2.64
1986	1.52	0.96	0.14	0.02	0.00							2.63
1987	0.13	0.30	0.28	0.06	0.01	0.03						0.81
1988	0.23	0.37	0.06	0.01	0.01							0.68
1989	0.43	0.19	0.22	0.03	0.00							0.86
1990	0.40	1.17	0.61	0.06	0.01			0.01				2.27
1991	0.28	1.19	0.41	0.01	0.00							1.89
1992	0.68	0.30	0.41	0.01	0.00							1.40
1993	0.00	0.14	0.17	0.00	0.00							0.31
1994	1.15	0.58	0.04	0.09	0.0							1.86

Table 16. Mean catch per tow (numbers) at age for NEFSC winter research vessel survey 1992-1994, strata 1-12, 25, 61-76 offshore and strata 1-56 inshore.

	Age											
Winter Year	0	1	2	3	4	5	6	7	8	9	10	Total
1992	0.00	0.68	3.33	1.16	0.12	0.01	0.00	0.00	0.00	0.00	0.00	5.30
1993	0.00	0.18	1.37	2.10	0.37	0.12	0.00	0.00	0.00	0.00	0.00	4.14
1994	0.00	0.16	0.08	0.26	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.64
1995												2.41

Table 17. Mean catch per tow (numbers) at age for Massachusetts spring and autumn research vessel surveys, 1984-1993. Strata 11-21.

Spring						Age						
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984			0.40	0.64	0.41	0.12	0.02	0.02				1.61
1985		0.04	0.15	0.41	0.51	0.02	0.08					1.21
1986		0.04	0.69	0.60	0.12	0.04	0.02	0.01	0.03			1.55
1987			0.34	0.32	0.05							0.71
1988			0.07	0.23	0.07	0.03			0.02			0.42
1989			0.52	0.35	0.12	0.07	0.02					1.08
1990		0.01	0.04	0.37	0.09	0.12	0.04			0.02		0.69
1991			0.02	0.01	0.07	0.21	0.02	0.02		0.02		0.37
1992			0.04	0.02		0.03						0.09
1993				0.04	0.06			0.02				0.12
1994				0.05	0.05	0.07	0.05					0.22

Autumn						Age						
Year	0	1	2	3	4	5	6	7	8	9	10	Total
1984	201.29	0.34	0.06	0.32	0.18	0.02						202.21
1985	196.58	0.75	0.05	0.28	0.28	0.04						197.98
1986	78.69	0.04	0.18	0.61	0.04							79.56
1987	34.17	0.32	0.15	0.21								34.85
1988	58.10	2.34	0.16	0.06	0.04							60.70
1989	6.52		0.07	0.03								6.62
1990	4.15	0.06		0.02	0.02			0.04				4.29
1991	9.30	0.16										9.46
1992	10.82	0.00		0.09	0.09							11.00
1993	0.98	0.06	0.02									1.06
1994	45.03		0.01	0.02	0.01							45.07

Table 18. Rhode Island Division of Fisheries and Wildlife research trawl survey 1979-1994. Spring and fall combined young of the year (YOY) (< 11 cm) and total catch per unit effort index. Virginia Institute of Marine Science (VIMS) black sea bass index from the lower James River and Chesapeake Bay.

	RI DFW		VIMS
Year	YOY	Mean #/tow	Geometric Mean
1979	0.09	0.13	
1980	0.06	0.11	
1981	15.28	15.68	
1982	0.10	0.14	
1983	0.66	0.74	
1984	4.03	4.14	
1985	4.02	4.08	
1986	5.87	15.69	
1987	0.20	0.32	1.571
1988	0.69	0.69	0.835
1989	0.17	0.17	2.357
1990	0.38	0.38	1.118
1991	0.16	0.23	1.286
1992	0.49	0.61	0.225
1993	0.02	0.03	1.040
1994	0.09	0.12	

Table 19. Growth and maturity parameters for black sea bass.

Length-weight equations:

NEFSC spring	$WT_{gr} = 0.0246 * LEN_{cm}^{2.796}$
NEFSC autumn	$WT_{gr} = 0.0190 * LEN_{cm}^{2.912}$
NEFSC combined	$WT_{gr} = 0.0218 * LEN_{cm}^{2.854}$
Mercer (1978)	$WT_{gr} = 0.00001 * \text{Std. } LEN_{mm}^{3.1798}$
	$TL_{mm} = -11.2 + 1.340 * \text{Std } LEN_{mm}$
	$WT_{gr} = 0.0212 * \text{Std. } LEN_{cm}^{3.0991}$
	$TL_{cm} = 1.78 + 1.24 * \text{Std } LEN_{cm}$

Growth equations

NEFSC	$Len_{cm} = 66.27 * (1-e^{-0.168(t-0.715)})$
Mercer (1978)	$\text{Std } Len_{mm} = 469 * (1-e^{-0.182(t+0.1056)})$
Alexander (1981)	$\text{Std } Len_{mm} = 441.03 * (1-e^{-0.201(t-0.1262)})$

Maturity at Age

% mature

	O'Brien *et al.*			Alexander (1981)			Caruso (1995)		
Age	F	M	n	F	M	n	F	M	n
0	0	0	-	-	-	0	-	-	0
1	0.13	0.08	-	1.0	0	2	-	-	0
2	0.60	0.72	-	1.0	0.995	124	0.99	1.0	200
3	0.87	0.93	-	1.0	1.0	227	1.0	1.0	567
4	0.93	0.98	-	1.0	1.0	180	1.0	1.0	133
5	1.0	1.0	-	1.0	1.0	182	1.0	1.0	71
6+	1.0	1.0	-	1.0	1.0	67	1.0	1.0	52
n =	561	348							

Table 20. VPA results for black sea bass using ADAPT.

INPUT PARAMETERS AND OPTIONS SELECTED

Natural mortality is 0.2 and the oldest age (not in the plus group) is 5

For all yrs prior to the terminal year (1993), backcalculated stock sizes for the following ages used to estimate total mortality (Z) for age 5: 3 4 5

This method for estimating F on the oldest age is generally used when a flat-topped partial recruitment curve is thought to be characteristic of the stock.

F for age 6+ is then calculated from the ratios of F[age 6+] to F[age 5] = 1.0

Stock size of the 6+ group is then calculated using the method: CATCHEQ

Partial recruitment estimate for 1993

1	0.0010
2	0.1150
3	0.4900
4	1.0000
5	1.0000
6	1.0000

Objective function is SUM w*(LOG(OBS) - LOG(PRED))**2

Indices normalized (by dividing by mean observed value) before tuning to VPA stocksizes.

The residuals for years prior to the terminal year are not downweighted.

Biomass estimates (other than SSB) reflect mean stock sizes. SSB calculated as in the NEFSC projection program (see note below SSB table for description of the algorithm).

Initial estimates of parameters for the Marquardt algorithm and lower and upper bounds on the parameter estimates:

Par.	Initial Est	Lower Bnd	Upper Bnd
N 1	5.0000000E1	0.0000000E0	1.0000000E6
N 2	5.0000000E1	0.0000000E0	1.0000000E6
N 3	5.0000000E1	0.0000000E0	1.0000000E6
N 4	4.0000000E1	0.0000000E0	1.0000000E6
N 5	4.0000000E1	0.0000000E0	1.0000000E6
qSV SPR 1	1.0000000E-4	0.0000000E0	1.0000000E0
qSV SPR 2	1.0000000E-4	0.0000000E0	1.0000000E0
qSV SPR 3	1.0000000E-4	0.0000000E0	1.0000000E0
qSV SPR 4	1.0000000E-4	0.0000000E0	1.0000000E0
qSV SPR 5	1.0000000E-4	0.0000000E0	1.0000000E0
qSV SPR 6	1.0000000E-4	0.0000000E0	1.0000000E0

The following indices of abundance are used in this run:

8	NEFSC SV SPR 1
9	NEFSC SV SPR 2
10	NEFSC SV SPR 3
11	NEFSC SV SPR 4
12	NEFSC SV SPR 5
13	NEFSC SV SPR 6

Table 20 continued.

Obs Indices (before transformation) by index & yr; with index means

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	******
8 ■	0.010	0.080	0.150	0.020	0.390	0.200	0.350	0.630	0.320	0.000	0.010	0.216
9 ■	0.070	0.080	1.180	0.670	0.700	0.410	0.200	0.210	0.560	0.800	0.030	0.446
10 ■	0.070	0.130	0.500	0.350	0.620	0.100	0.230	0.060	0.640	0.560	0.140	0.309
11 ■	0.050	0.120	0.060	0.060	0.130	0.030	0.030	0.030	0.100	0.030	0.060	0.064
12 ■	0.010	0.020	0.000	0.040	0.080	0.000	0.010	0.000	0.010	0.000	0.010	0.026
13 ■	0.010	0.010	0.000	0.030	0.030	0.020	0.000	0.000	0.010	0.000	0.000	0.018

SUMMARY OF WEIGHTING USED IN THE OBJECTIVE FUNCTION:

EXOGENOUS WEIGHTS BY INDEX AND YR (omega) = 1.00

DOWNWEIGHTS BY YEAR (delta) = 1.00

ITERATIVE RE-WEIGHTS BY INDEX (chi)

■	8	9	10	11	12	13
■	0.0705	0.1970	0.1818	0.2392	0.2149	0.0966

CATCH AT AGE (thousands)

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1 ■	1945	2267	5881	1651	2945	890	2439	1987	1126	945
2 ■	2910	3840	19844	4568	5570	4576	3514	7021	5879	8569
3 ■	3608	2561	4595	4334	3987	2593	5107	2144	3404	2699
4 ■	1657	1633	951	586	973	793	617	1096	579	538
5 ■	139	276	233	161	269	153	162	571	36	35
6 ■	80	234	393	139	39	96	26	53	30	22
1+■	10339	10811	31897	11439	13783	9101	11865	12872	11054	12808

CAA summary for ages 3 6

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
■	7429	4704	6172	5220	5268	3635	5912	3864	4049	3249

WT AT AGE (MID-YR) in kg.

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1 ■	0.077	0.049	0.073	0.073	0.062	0.042	0.052	0.049	0.067	0.095
2 ■	0.166	0.154	0.185	0.176	0.192	0.184	0.176	0.161	0.190	0.201
3 ■	0.293	0.264	0.394	0.334	0.320	0.342	0.324	0.307	0.308	0.321
4 ■	0.470	0.519	0.663	0.534	0.413	0.474	0.527	0.509	0.545	0.584
5 ■	0.852	0.849	0.997	0.782	0.518	0.741	0.692	0.631	0.994	0.927
6 ■	1.214	1.256	1.333	1.328	1.164	1.189	1.179	1.194	1.284	1.383

Table 20 continued.

WT AT AGE (JAN 1) in kg.

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1	0.054	0.019	0.015	0.015	0.021	0.016	0.012	0.014	0.031	0.019	0.019
2	0.132	0.109	0.095	0.113	0.118	0.107	0.086	0.091	0.096	0.116	0.463
3	0.220	0.209	0.246	0.249	0.237	0.256	0.244	0.232	0.223	0.247	0.348
4	0.350	0.390	0.418	0.459	0.371	0.389	0.425	0.406	0.409	0.424	0.417
5	0.633	0.632	0.719	0.720	0.526	0.553	0.573	0.577	0.711	0.711	0.804
6	1.214	1.256	1.333	1.328	1.164	1.189	1.179	1.194	1.284	1.383	1.383

Weights at age at the start of the spawning season are assumed to be the same as the mid-year weight at age estimates.

RESULTS

APPROXIMATE STATISTICS ASSUMING LINEARITY NEAR SOLUTION

SUM OF SQUARES	5.977542
ORTHOGONALITY OFFSET.........	0.003905
MEAN SQUARE RESIDUALS	0.129947

	PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
N 1	1.57929E3	2.27200E3	6.95112E-1	1.44
N 2	1.18276E3	1.01361E3	1.16687E0	0.86
N 3	5.29176E3	4.25233E3	1.24444E0	0.80
N 4	2.67142E3	1.83115E3	1.45887E0	0.69
N 5	1.49215E2	1.21430E2	1.22881E0	0.81
qSV SPR 1	3.16597E-5	1.44533E-5	2.19049E0	0.46
qSV SPR 2	5.71740E-5	1.49256E-5	3.83061E0	0.26
qSV SPR 3	1.32268E-4	3.55713E-5	3.71838E0	0.27
qSV SPR 4	6.22096E-4	1.44994E-4	4.29049E0	0.23
qSV SPR 5	3.37203E-3	9.98795E-4	3.37609E0	0.30
qSV SPR 6	6.94516E-3	3.30457E-3	2.10168E0	0.48

CATCHABILITY ESTIMATES IN ORIGINAL UNITS

	ESTIMATE	STD. ERR.	C.V.
qSV SPR 1	6.33195E-6	2.89066E-6	0.46
qSV SPR 2	2.53645E-5	6.62152E-6	0.26
qSV SPR 3	4.07624E-5	1.09624E-5	0.27
qSV SPR 4	3.90224E-5	9.09509E-6	0.23
qSV SPR 5	7.58706E-5	2.24729E-5	0.30
qSV SPR 6	1.38903E-4	6.60914E-5	0.48

Table 20 continued.

CORRELATION BETWEEN PARAMETERS ESTIMATED (SYMBOLIC FORM)

```
N 1         * . . . . - . . . . .
N 2         . * . . . . - . . . .
N 3         . . * . . . . - . . .
N 4         . . . * . . . . - . .
N 5         . . . . * . . . . - .
qSV  SPR 1  - . . . . * . . . . .
qSV  SPR 2  . - . . . . * . . . .
qSV  SPR 3  . . - . . . . * . . .
qSV  SPR 4  . . . - . . . . * . .
qSV  SPR 5  . . . . - . . . . * .
qSV  SPR 6  . . . . . . . . . . *
```

```
SYMBOLS:  =  LARGE NEGATIVE CORRELATION     whenever  -1 <= R <   -L
          -  MODERATE NEGATIVE CORRELATION  whenever  -L <= R <   -M
          .  SMALL CORRELATION              whenever  -M <= R <= +M
          +  MODERATE POSITIVE CORRELATION  whenever  +M <   R <= +L
          *  LARGE POSITIVE CORRELATION     whenever  +L <   R <= +1
```

Where R is the estimated correlation, M is 0.2 and L is 0.5

SUMMARY OF RESIDUALS

Index 8 SV SPR 1 tuned to the sum of Jan1 full stock sizes (number) for age 1.

Yr	Observed	Pred	Weight	Wt Res	Std Res	Pred Stocksize
1984	-2.9957	-0.6229	0.2656	-0.6301	-1.7480	16942.215
1985	-0.9163	0.2107	0.2656	-0.2993	-0.8302	38992.594
1986	-0.5978	-0.3903	0.2656	-0.0551	-0.1529	21379.557
1987	-2.3026	-0.6443	0.2656	-0.4403	-1.2216	16582.896
1988	0.6419	-0.4488	0.2656	0.2896	0.8034	20164.851
1989	-0.1054	-1.0956	0.2656	0.2630	0.7295	10560.286
1990	0.2624	-0.4978	0.2656	0.2019	0.5600	19200.601
1991	1.1474	-0.4849	0.2656	0.4335	1.2024	19449.341
1992	0.4700	-0.4223	0.2656	0.2370	0.6573	20705.745
1994	-2.9957	-2.9957	0.2656	0.0000	0.0000	1579.293

Partial variance for this index is 0.137307

Index 9 SV SPR 2 tuned to the sum of Jan1 full stock sizes (number) for age 2.

Yr	Observed	Pred	Weight	Wt Res	Std Res	Pred Stocksize
1984	-2.1830	-0.7000	0.4438	-0.6582	-1.8259	8685.407
1985	-1.7130	-0.3675	0.4438	-0.5972	-1.6565	12111.204
1986	0.9783	0.5353	0.4438	0.1966	0.5454	29873.170
1987	0.4123	-0.3616	0.4438	0.3435	0.9528	12182.752
1988	0.4417	-0.3699	0.4438	0.3602	0.9992	12083.040
1989	-0.0788	-0.2337	0.4438	0.0687	0.1907	13844.837
1990	-0.7967	-0.8023	0.4438	0.0025	0.0069	7840.725
1991	-0.7479	-0.2580	0.4438	-0.2174	-0.6032	13513.224
1992	0.2329	-0.2136	0.4438	0.1982	0.5498	14125.861
1993	0.5896	-0.0932	0.4438	0.3031	0.8407	15933.583
1994	-2.6938	-2.6938	0.4438	0.0000	0.0000	1182.756

Partial variance for this index is 0.137378

Table 20 continued.

Index 10 SV SPR 3 tuned to the sum of Jan1 full stock sizes (number) for age 3.

Yr	Observed	Pred	Weight	Wt Res	Std Res	Pred Stocksize
1984	-1.4822	-0.1257	0.4263	-0.5783	-1.6043	6667.371
1985	-0.8632	-0.5238	0.4263	-0.1447	-0.4014	4477.933
1986	0.4839	-0.1602	0.4263	0.2746	0.7618	6441.239
1987	0.0983	-0.1507	0.4263	0.1062	0.2945	6502.489
1988	0.6990	-0.2580	0.4263	0.4080	1.1319	5841.096
1989	-1.1255	-0.4434	0.4263	-0.2908	-0.8068	4852.812
1990	-0.2926	-0.0496	0.4263	-0.1036	-0.2874	7194.658
1991	-1.6363	-0.8474	0.4263	-0.3364	-0.9331	3239.844
1992	0.7308	-0.4731	0.4263	0.5133	1.4238	4710.828
1993	0.5972	-0.1910	0.4263	0.3361	0.9323	6245.738
1994	-0.7890	-0.3568	0.4263	-0.1843	-0.5113	5291.762

Partial variance for this index is 0.133895

Index 11 SV SPR 4 tuned to the sum of Jan1 full stock sizes (number) for age 4.

Yr	Observed	Pred	Weight	Wt Res	Std Res	Pred Stocksize
1984	-0.2268	0.3825	0.4891	-0.2980	-0.8267	2356.482
1985	0.5617	0.3111	0.4891	0.1225	0.3400	2194.128
1986	-0.0445	-0.1753	0.4891	0.0640	0.1776	1348.933
1987	-0.0445	-0.3650	0.4891	0.1568	0.4349	1115.913
1988	0.7287	-0.1366	0.4891	0.4232	1.1741	1402.222
1989	-0.7376	-0.3136	0.4891	-0.2073	-0.5752	1174.698
1990	-0.7376	0.0120	0.4891	-0.3666	-1.0171	1626.903
1991	-0.7376	-0.2361	0.4891	-0.2453	-0.6805	1269.483
1992	0.4664	-0.8135	0.4891	0.6260	1.7365	712.589
1993	-0.7376	-0.7272	0.4891	-0.0051	-0.0141	776.834
1994	-0.0445	0.5079	0.4891	-0.2702	-0.7495	2671.421

Partial variance for this index is 0.110626

Index 12 SV SPR 5 tuned to the sum of Jan1 full stock sizes (number) for age 5.

Yr	Observed	Pred	Weight	Wt Res	Std Res	Pred Stocksize
1984	-0.8109	-0.2375	0.4635	-0.2658	-0.7374	233.865
1985	-0.1178	0.3716	0.4635	-0.2268	-0.6293	430.009
1987	0.2877	-0.1954	0.4635	0.2239	0.6212	243.912
1988	1.2685	0.2568	0.4635	0.4690	1.3009	383.397
1989	-0.8109	-0.1026	0.4635	-0.3283	-0.9108	267.636
1990	-0.8109	-0.1941	0.4635	-0.2859	-0.7931	244.226
1992	-0.8109	-1.8281	0.4635	0.4715	1.3080	47.663
1994	-0.8109	-0.6869	0.4635	-0.0575	-0.1596	149.215

Partial variance for this index is 0.130924

Index 13 SV SPR 6 tuned to the sum of Jan1 full stock sizes (number) for age 6.

Yr	Observed	Pred	Weight	Wt Res	Std Res	Pred Stocksize
1984	0.0000	-0.0865	0.3109	0.0269	0.0746	132.057
1985	-0.6931	0.9074	0.3109	-0.4976	-1.3803	356.774
1987	0.6931	0.3575	0.3109	0.1044	0.2895	205.853
1988	0.4055	-0.9773	0.3109	0.4299	1.1925	54.186
1989	-0.6931	0.1359	0.3109	-0.2577	-0.7149	164.940
1992	-0.6931	-1.3178	0.3109	0.1942	0.5387	38.549

Partial variance for this index is 0.131541

Table 20 continued.

Standardized residuals by index & yr; with row/column/grand means

	1984	1985	1986	1987	1988	1989	1990	1991
8	-1.7480	-0.8302	-0.1529	-1.2216	0.8034	0.7295	0.5600	1.2024
9	-1.8259	-1.6565	0.5454	0.9528	0.9992	0.1907	0.0069	-0.6032
10	-1.6043	-0.4014	0.7618	0.2945	1.1319	-0.8068	-0.2874	-0.9331
11	-0.8267	0.3400	0.1776	0.4349	1.1741	-0.5752	-1.0171	-0.6805
12	-0.7374	-0.6293	-99.0000	0.6212	1.3009	-0.9108	-0.7931	-99.0000
13	0.0746	-1.3803	-99.0000	0.2895	1.1925	-0.7149	-99.0000	-99.0000
**	-1.1113	-0.7596	0.3330	0.2286	1.1003	-0.3479	-0.3061	-0.2536

	1992	1993	1994	*******
8	0.6573	-99.0000	0.0000	0.0000
9	0.5498	0.8407	0.0000	0.0000
10	1.4238	0.9323	-0.5113	0.0000
11	1.7365	-0.0141	-0.7495	0.0000
12	1.3080	-99.0000	-0.1596	0.0000
13	0.5387	-99.0000	-99.0000	0.0000
**	1.0357	0.5863	-0.2841	0.0000

-99 in the above table indicates a missing value

Percent of total sum of squares by index & yr; with row/column sums

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
8	6.64	1.50	0.05	3.24	1.40	1.16	0.68	3.14	0.94	-99.00
9	7.25	5.97	0.65	1.97	2.17	0.08	0.00	0.79	0.66	1.54
10	5.60	0.35	1.26	0.19	2.79	1.42	0.18	1.89	4.41	1.89
11	1.49	0.25	0.07	0.41	3.00	0.72	2.25	1.01	6.56	0.00
12	1.18	0.86	-99.00	0.84	3.68	1.80	1.37	-99.00	3.72	-99.00
13	0.01	4.14	-99.00	0.18	3.09	1.11	-99.00	-99.00	0.63	-99.00
**	22.16	13.07	2.03	6.84	16.13	6.28	4.48	6.83	16.91	3.43

	1994	*******
8	0.00	18.76
9	0.00	21.07
10	0.57	20.53
11	1.22	16.96
12	0.06	13.51
13	-99.00	9.17
**	1.84	100.00

-99 in the above table indicates a missing value

Partial variance (and proportion of total) by index

	8	9	10	11	12	13
**	0.13730681	0.13737843	0.13389547	0.11062595	0.13092411	0.13154144
**	0.17565779	0.17574941	0.17129363	0.14152473	0.16749234	0.16828210

	***********
**	0.78167221
**	1.00000000

Table 20 continued.

STOCK NUMBERS (Jan 1) in thousands

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	16942	38993	21380	16583	20165	10560	19201	19449	20706	2489
2	8685	12111	29873	12183	12083	13845	7841	13513	14126	15934
3	6667	4478	6441	6502	5841	4853	7195	3240	4711	6246
4	2356	2194	1349	1116	1402	1175	1627	1269	713	777
5	234	430	319	244	383	268	244	774	48	60
6	132	357	523	206	54	165	38	70	39	37
1+	35017	58563	59885	36833	39928	30865	36147	38315	40343	25543

	1994
1	1579
2	1183
3	5292
4	2671
5	149
6	28
1+	10902

Summaries for ages 3-6

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	9390	7459	8632	8068	7680	7680	9104	5353	5511	7120	8140

FISHING MORTALITY

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0.14	0.07	0.36	0.12	0.18	0.10	0.15	0.12	0.06	0.54
2	0.46	0.43	1.32	0.54	0.71	0.45	0.68	0.85	0.62	0.90
3	0.91	1.00	1.55	1.33	1.40	0.89	1.53	1.31	1.60	0.65
4	1.50	1.73	1.51	0.87	1.46	1.37	0.54	3.08	2.28	1.45
5	1.07	1.24	1.65	1.31	1.49	1.00	1.32	1.69	1.80	1.05
6	1.07	1.24	1.65	1.31	1.49	1.00	1.32	1.69	1.80	1.05

Avg F for ages 3 - 5

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	1.16	1.32	1.57	1.17	1.45	1.09	1.13	2.03	1.89	1.05

BACKCALCULATED PARTIAL RECRUITMENT

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	0.09	0.04	0.22	0.09	0.12	0.07	0.10	0.04	0.03	0.38
2	0.31	0.25	0.80	0.40	0.48	0.33	0.45	0.28	0.27	0.62
3	0.61	0.58	0.94	1.00	0.94	0.65	1.00	0.43	0.70	0.45
4	1.00	1.00	0.92	0.65	0.98	1.00	0.35	1.00	1.00	1.00
5	0.71	0.71	1.00	0.98	1.00	0.73	0.86	0.55	0.79	0.72
6	0.71	0.71	1.00	0.98	1.00	0.73	0.86	0.55	0.79	0.72

Table 20 continued.

MEAN BIOMASS (mt)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	1108	1677	1194	1038	1042	384	842	816	1220	167
2	1054	1383	2836	1518	1522	1869	916	1345	1835	1941
3	1179	688	1197	1110	931	1009	1107	512	672	1351
4	532	505	428	366	283	281	605	189	143	222
5	113	194	145	99	96	116	87	219	20	31
6	91	238	318	141	30	114	23	37	21	29
1+	4078	4685	6117	4272	3904	3773	3576	3118	3911	3741

Summaries for ages 3 6

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	1915	1625	2088	1716	1340	1520	1822	957	856	1633

CATCH BIOMASS (mt)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	150	111	433	121	183	38	127	98	76	91
2	488	597	3756	812	1084	850	627	1148	1130	1751
3	1075	688	1859	1481	1307	901	1698	673	1077	877
4	799	872	647	318	412	385	329	584	327	322
5	121	239	239	129	143	115	115	371	37	33
6	97	294	524	185	45	114	31	63	39	30
1+	2730	2802	7458	3046	3175	2403	2926	2937	2685	3103

Summaries for ages 3 6

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	1941	1983	2836	1992	1724	1478	2045	1594	1404	1171

SSB AT THE START OF THE SPAWNING SEASON - males & females (mt)

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1	113	168	126	105	107	39	86	83	122	18
2	734	958	2171	1068	1095	1299	657	985	1304	1428
3	1203	709	1289	1178	993	1028	1191	543	726	1336
4	635	610	511	413	337	332	655	231	176	264
5	130	227	174	116	114	132	102	264	25	36
6	105	278	382	166	36	131	27	45	26	33
1+	2919	2950	4654	3046	2682	2961	2718	2150	2380	3115

Table 20 continued.

The above SSBs by age (a) and year (y) are calculated following the algorithm used in the NEFSC projection program, i.e.

$$SSB(a,y) = W(a,y) \times P(a,y) \times N(a,y) \times \exp[-Z(a,y)]$$

where $Z(a,y) = 0.53 \times M(a,y) + 0.3 \times F(a,y)$
N(a,y) - Jan 1 stock size estimates (males & females)
P(a,y) - proportion mature (generally females)
W(a,y) - weight at age at the beginning of the spawning season

The W(a,y) are assumed to be the same as the mid-year weight at age estimates (see "WT AT AGE" table in input section).

MEAN STOCK NUMBERS (thousands)

■	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
1 ■	14392	34231	16352	14214	16807	9133	16191	16646	18216	1756
2 ■	6351	8980	15327	8627	7926	10160	5206	8353	9656	9654
3 ■	4025	2608	3038	3325	2909	2952	3416	1669	2183	4209
4 ■	1132	972	646	686	685	592	1148	372	263	380
5 ■	132	228	145	126	185	156	125	347	21	34
6 ■	75	189	238	106	26	96	20	31	17	21
1+■	26107	47208	35747	27083	28538	23090	26106	27418	30356	16054

Table 21. Black sea bass bootstrap results.

NUMBER OF BOOTSTRAP REPLICATIONS ATTEMPTED: 500
Results from the converged replications are used for computing the statistics that follow. Other replications are ignored.

BOOTSTRAP OUTPUT VARIABLE: Age-specific stocksizes (on Jan 1, 1994) estimated by NLLS

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1.183E3	1.5903E3	1.196E3	1.01
5.292E3	6.476E3	4.425E3	0.84
2.671E3	3.195E3	1.935E3	0.72
1.492E2	1.786E2	1.305E2	0.87

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
4.072E2	5.350E1	34.43	7.756E2	1.54
1.184E3	1.979E2	22.37	4.108E3	1.08
5.235E2	8.654E1	19.60	2.148E3	0.90
2.940E1	5.837E0	19.70	1.198E2	1.09

BOOTSTRAP OUTPUT VARIABLE: Catchability estimates (q) for each index of abundance used in the ADAPT run. Note that these q's have been re-scaled to original units.

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
6.332E-6	6.746E-6	2.659E-6	0.42
2.536E-5	2.584E-5	6.601E-6	0.26
4.076E-5	4.299E-5	1.025E-5	0.25
3.902E-5	3.977E-5	8.752E-6	0.22
7.587E-5	7.808E-5	2.113E-5	0.28
1.389E-4	1.527E-4	6.700E-5	0.48

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
4.138E-7	1.189E-7	6.54	5.918E-6	0.45
4.797E-7	2.952E-7	1.89	2.488E-5	0.27
2.226E-6	4.582E-7	5.46	3.854E-5	0.27
7.492E-7	3.914E-7	1.92	3.827E-5	0.23
2.208E-6	9.450E-7	2.91	7.366E-5	0.29
1.377E-5	2.996E-6	9.91	1.251E-4	0.54

Table 21 continued.

BOOTSTRAP OUTPUT VARIABLE: Full vector of age-specific stocksizes on Jan 1, 1994

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1.579E3	3.354E3	4.419E3	2.80
1.183E3	1.590E3	1.196E3	1.01
5.292E3	6.476E3	4.425E3	0.84
2.671E3	3.195E3	1.935E3	0.72
1.492E2	1.786E2	1.305E2	0.87
2.758E1	2.910E1	1.500E1	0.54

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
1.775E3	1.976E2	112.39	-1.957E2	-22.58
4.072E2	5.350E1	34.43	7.756E2	1.54
1.184E3	1.979E2	22.37	4.108E3	1.08
5.235E2	8.654E1	19.60	2.148E3	0.90
2.940E1	5.837E0	19.70	1.198E2	1.09
1.517E0	6.708E-1	5.50	2.607E1	0.58

BOOTSTRAP OUTPUT VARIABLE: Full vector of age-specific terminal F's (in 1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
5.440E-1	6.178E-1	3.634E-1	0.67
9.023E-1	9.868E-1	4.557E-1	0.51
6.493E-1	6.901E-1	2.970E-1	0.46
1.450E0	1.550E0	5.608E-1	0.39
1.050E0	1.120E0	3.233E-1	0.31
1.050E0	1.120E0	3.233E-1	0.31

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
7.373E-2	1.625E-2	13.55	4.703E-1	0.77
8.447E-2	2.038E-2	9.36	8.178E-1	0.56
4.084E-2	1.328E-2	6.29	6.085E-1	0.49
9.997E-2	2.508E-2	6.89	1.350E0	0.42
7.040E-2	1.446E-2	6.71	9.792E-1	0.33
7.040E-2	1.446E-2	6.71	9.792E-1	0.33

BOOTSTRAP OUTPUT VARIABLE: Fully-recruited F in the terminal year (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
1.050E0	1.120E0	3.233E-1	0.31

Table 21 continued.

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
7.040E-2	1.446E-2	6.71	9.792E-1	0.33

BOOTSTRAP OUTPUT VARIABLE: Partial recruitment vector in the terminal year (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
3.752E-1	3.990E-1	2.508E-1	0.67
6.223E-1	6.218E-1	2.666E-1	0.43
4.478E-1	4.476E-1	2.189E-1	0.49
1.000E0	9.278E-1	1.498E-1	0.15
7.239E-1	6.877E-1	1.243E-1	0.17
7.239E-1	6.877E-1	1.243E-1	0.17

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
2.374E-2	1.122E-2	6.33	3.515E-1	0.71
-5.516E-4	1.192E-2	-0.09	6.229E-1	0.43
-2.239E-4	9.790E-3	-0.05	4.481E-1	0.49
-7.224E-2	6.699E-3	-7.22	1.072E0	0.14
-3.623E-2	5.558E-3	-5.00	7.601E-1	0.16
-3.623E-2	5.558E-3	-5.00	7.601E-1	0.16

BOOTSTRAP OUTPUT VARIABLE: Average partial recruitment over 1991-1993

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
7.344E-2	7.028E-2	1.635E-2	0.22
3.597E-1	3.476E-1	6.025E-2	0.17
5.118E-1	4.954E-1	7.677E-2	0.15
1.000E0	9.717E-1	6.115E-2	0.06
6.791E-1	6.623E-1	4.037E-2	0.06
6.791E-1	6.623E-1	4.037E-2	0.06

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
-3.160E-3	7.314E-4	-4.30	7.660E-2	0.21
-1.206E-2	2.695E-3	-3.35	3.717E-1	0.16
-1.636E-2	3.433E-3	-3.20	5.282E-1	0.15
-2.832E-2	2.735E-3	-2.83	1.028E0	0.06
-1.684E-2	1.805E-3	-2.48	6.959E-1	0.06
-1.684E-2	1.805E-3	-2.48	6.959E-1	0.06

Table 21 continued.

BOOTSTRAP OUTPUT VARIABLE: Mean stock biomass during the terminal year (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
3.748E3	4.253E3	1.274E3	0.34

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
5.053E2	5.698E1	13.48	3.243E3	0.39

BOOTSTRAP OUTPUT VARIABLE: SSB (males & females) at start of spawning season (1993)

NLLS ESTIMATE	BOOTSTRAP MEAN	BOOTSTRAP STD ERROR	C.V. FOR NLLS SOLN
3.116E3	3.459E3	9.551E2	0.31

BIAS ESTIMATE	BIAS STD ERROR	PERCENT BIAS	NLLS EST CORRECTED FOR BIAS	C.V FOR CORRECTED ESTIMATE
3.429E2	4.271E1	11.00	2.773E3	0.34

Table 22. Yield per recruit for black sea bass north of Cape Hatteras, NC..

Natural Mortality is Constant at 0.2, Last age is a True Age;

Age-specific Input data for Yield per Recruit Analysis

Age	Fish Mort Pattern	Nat Mort Pattern	Average Stock	Weights Catch
1	.0540	1.0000	.059	.064
2	.3160	1.0000	.162	.177
3	.6670	1.0000	.370	.321
4	1.0000	1.0000	.654	.524
5	1.0000	1.0000	.803	.798
6	1.0000	1.0000	1.196	1.254
7	1.0000	1.0000	1.031	1.132
8	1.0000	1.0000	1.656	1.437
9	1.0000	1.0000	1.836	1.931
10	1.0000	1.0000	1.997	1.997
11	1.0000	1.0000	2.163	2.163
12	1.0000	1.0000	2.380	2.380
13	1.0000	1.0000	2.575	2.575
14	1.0000	1.0000	2.747	2.747
15	1.0000	1.0000	2.898	2.898

Summary of Yield per Recruit Analysis:

Slope of the Yield/Recruit Curve at F=0.00: --------> 3.522
F level at slope=1/10 of the above slope (F0.1): ---> .176
Yield/Recruit corresponding to F0.1: ---> .2508
F level to produce maximum Yield/Recruit (Fmax): ---> .292
Yield/Recruit corresponding to Fmax: ---> .2668

	Fishing Mortality	Total Catch Number	Total Catch Weight	Total Stock Number	Total Stock Weight
	.000	.00000	.00000	5.2420	4.1893
	.100	.22608	.20266	4.3170	2.6368
F0.1	.176	.32333	.25084	3.8816	1.9910
	.200	.34653	.25776	3.7742	1.8429
Fmax	.292	.41549	.26676	3.4479	1.4253
	.300	.42029	.26673	3.4248	1.3978
	.400	.47050	.26132	3.1821	1.1262
	.500	.50734	.25182	3.0030	.9476
	.600	.53585	.24169	2.8644	.8228
	.700	.55879	.23207	2.7532	.7311
	.800	.57780	.22329	2.6614	.6610
	.900	.59392	.21541	2.5839	.6057
	1.000	.60783	.20837	2.5171	.5608
	1.100	.62003	.20208	2.4588	.5237
	1.200	.63085	.19647	2.4072	.4924
	1.300	.64056	.19142	2.3611	.4656
	1.400	.64934	.18688	2.3194	.4424
	1.500	.65735	.18276	2.2816	.4221
	1.600	.66470	.17902	2.2469	.4041
	1.700	.67148	.17560	2.2150	.3880
	1.800	.67777	.17246	2.1854	.3736
	1.900	.68363	.16957	2.1580	.3606
	2.000	.68911	.16689	2.1323	.3488

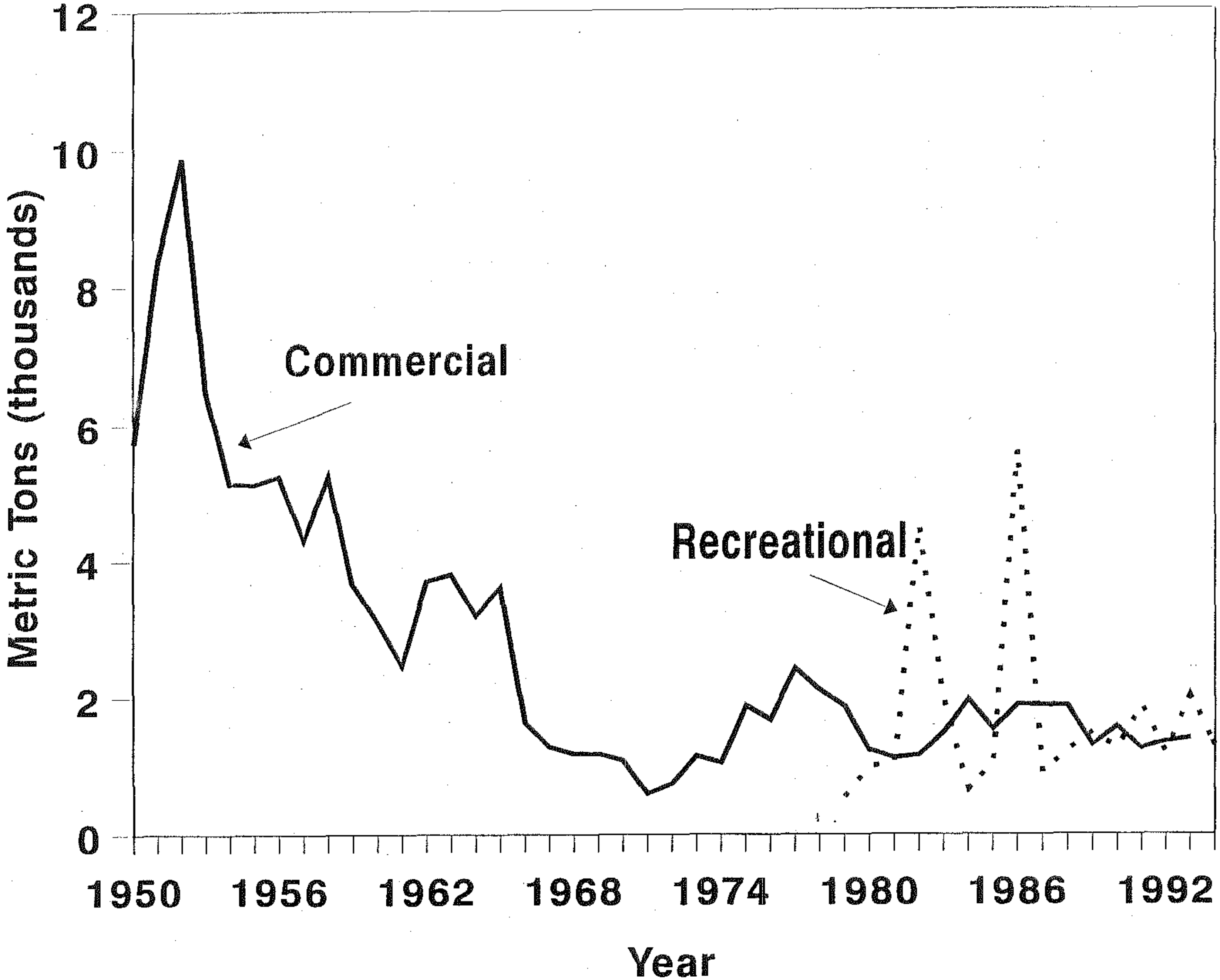

Figure 1. Total U.S. commercial and recreational landings of black sea bass, 1950 to 1994.

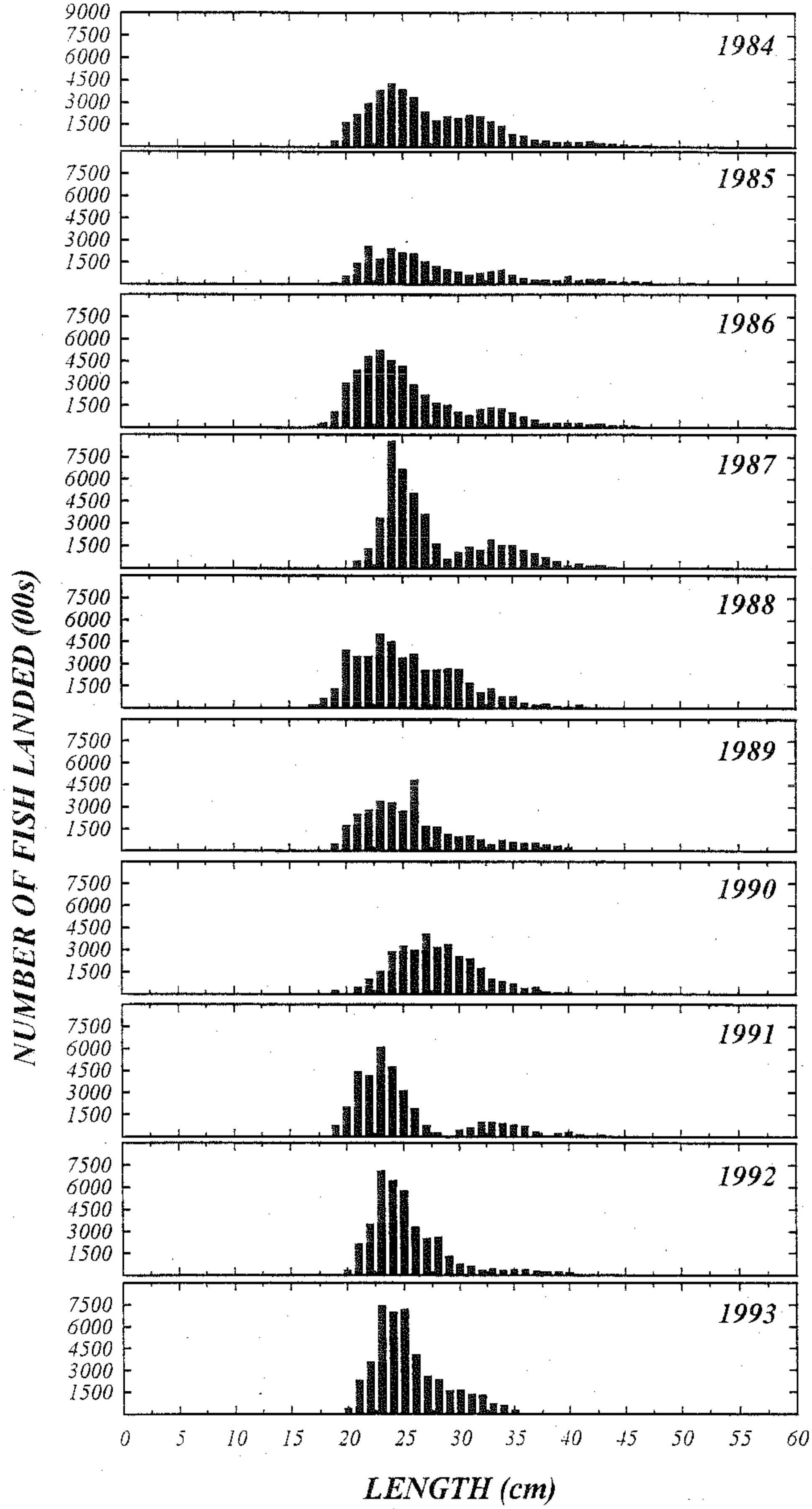

Figure 2. Commercial length frequencies for black sea bass, 1984-1993.

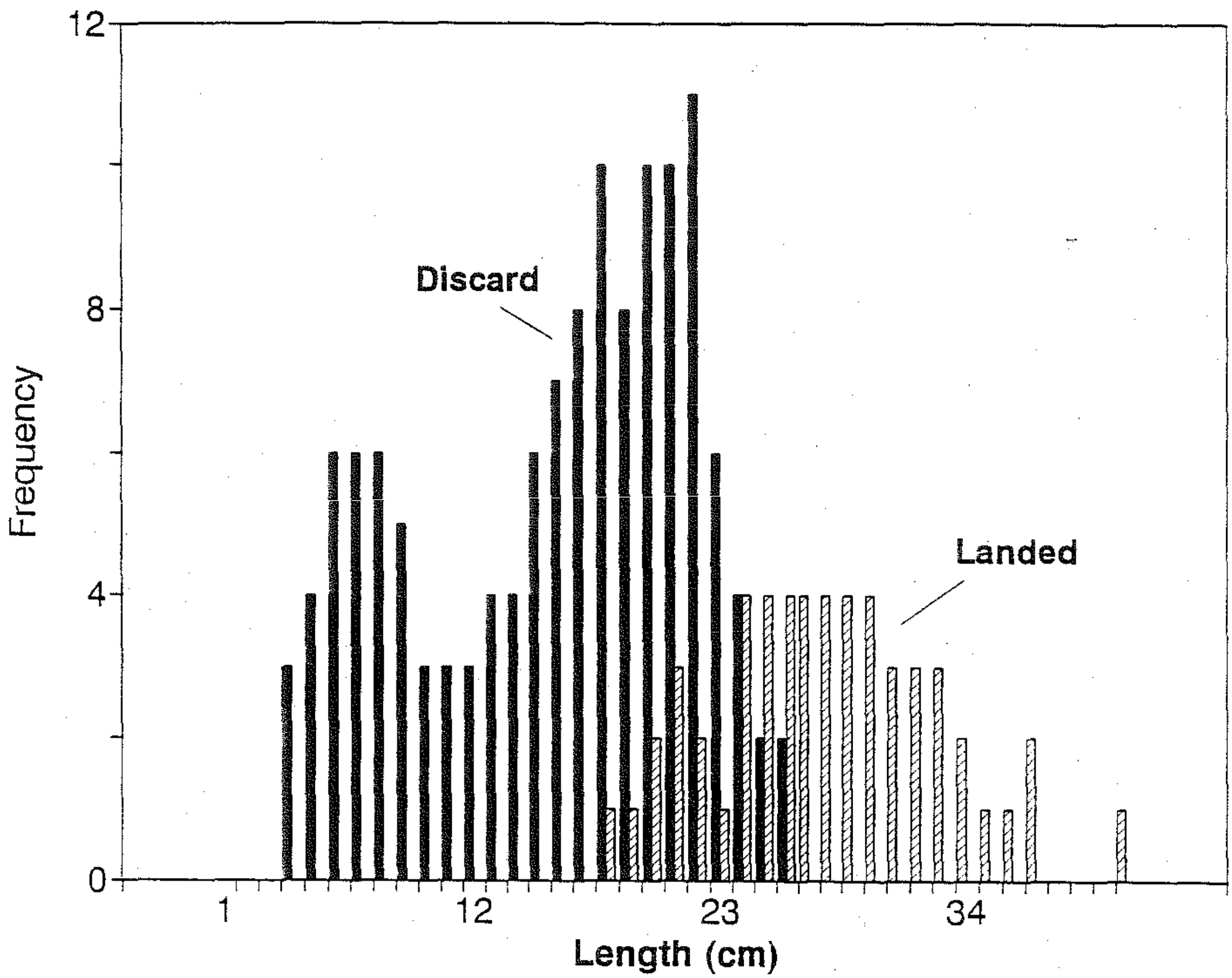

Figure 3. Length frequency of black sea bass otter trawl discards during quarter 1 of 1989.

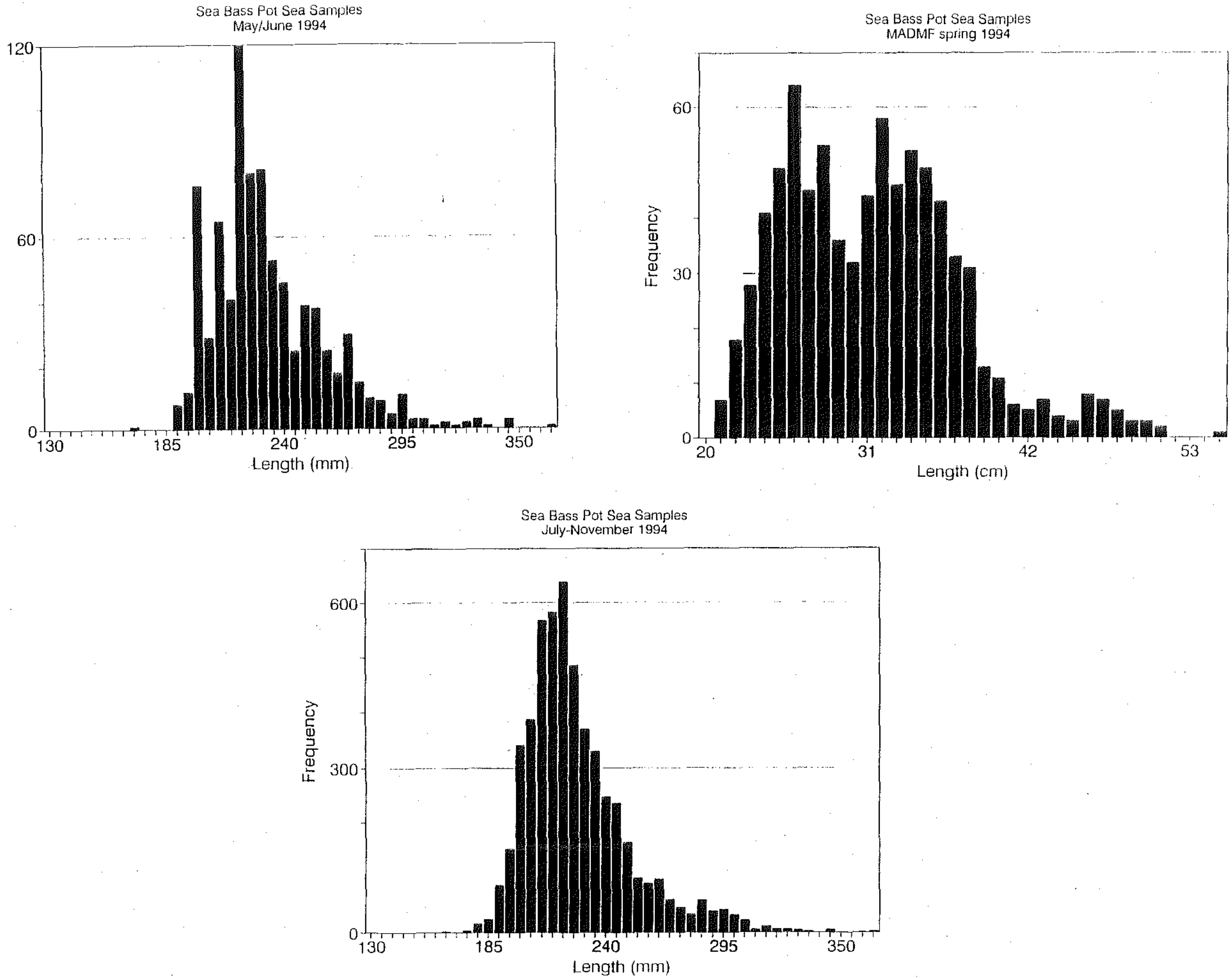

Figure 4. Length frequency of black sea bass discards in the pot fishery, Massachusetts 1993 and Mid-Atlantic 1994.

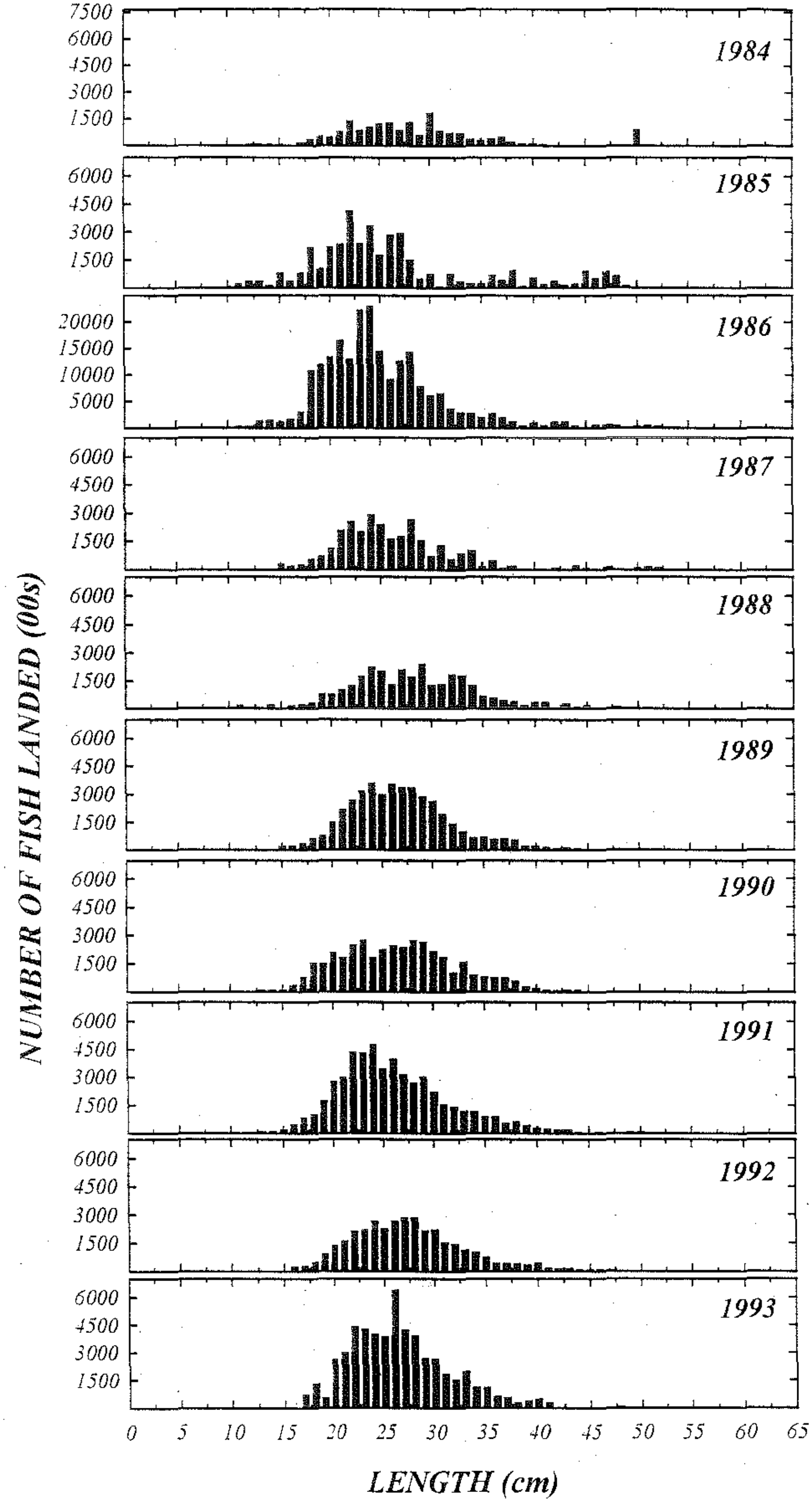

Figure 5. Recreational length frequencies for black sea bass, 1984-1993.

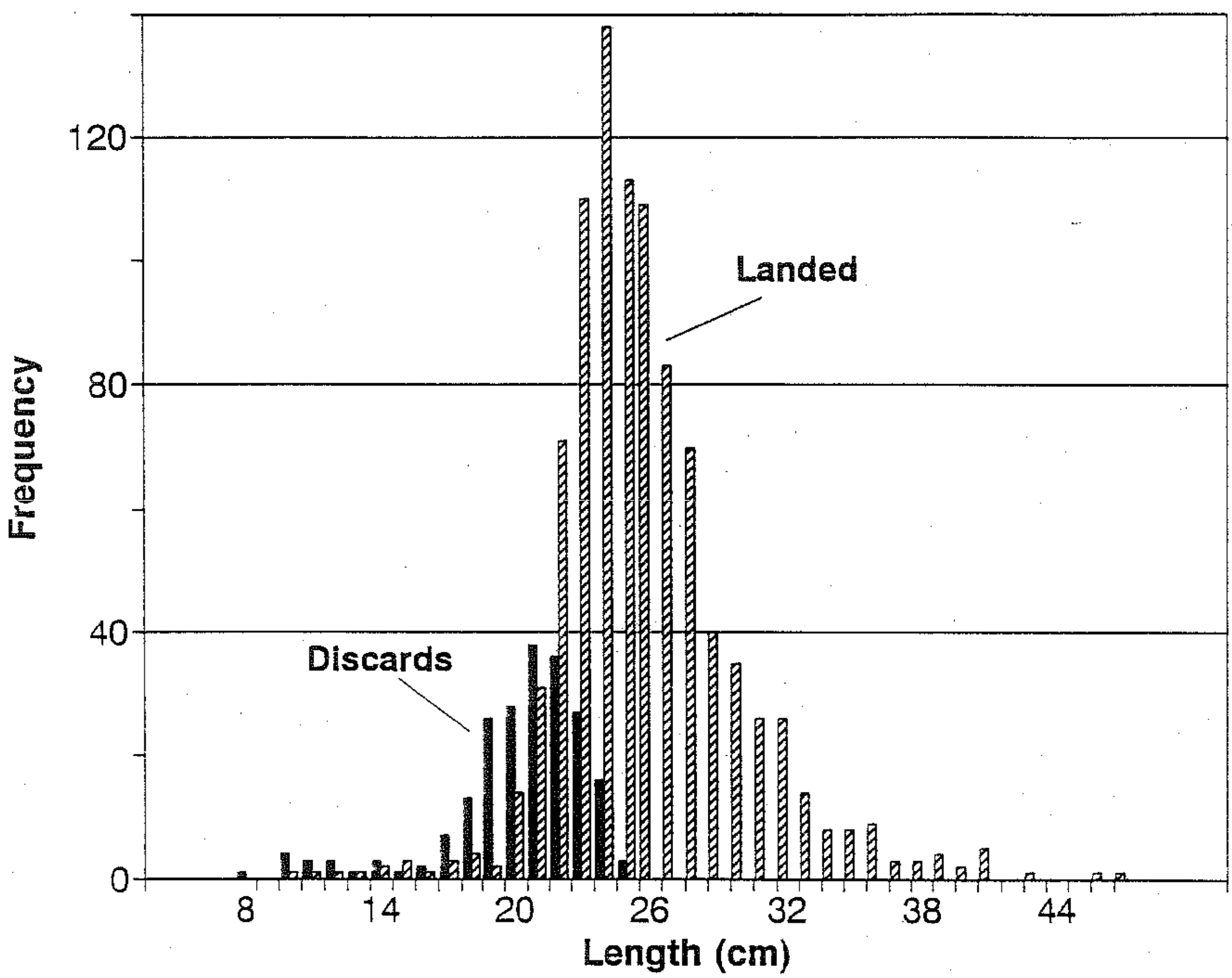

Figure 6. Length frequency of New York party boat landings and discards of black sea bass, 1992-1994.

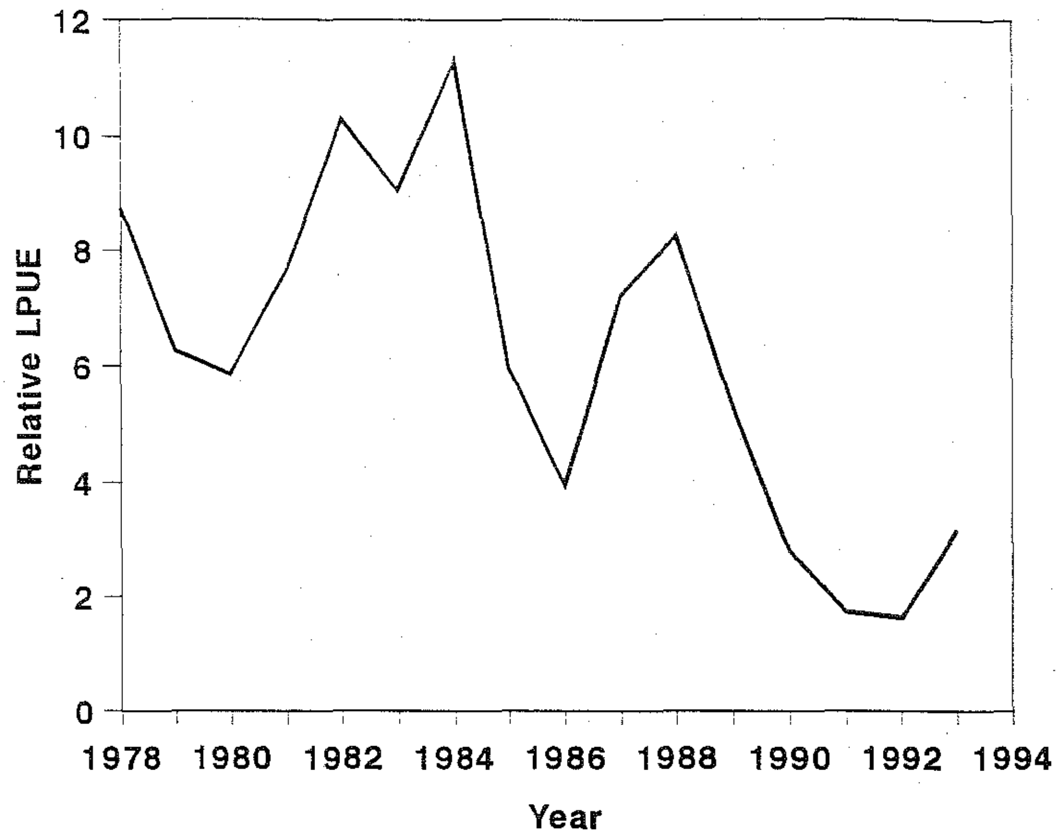

Figure 7. Relative commercial landings per unit effort as calculated by a GLM using otter trawl trips landings greater than 25% black sea bass from 1978-1993. Index is a standardized corrected re-transformed year coefficient representing abundance.

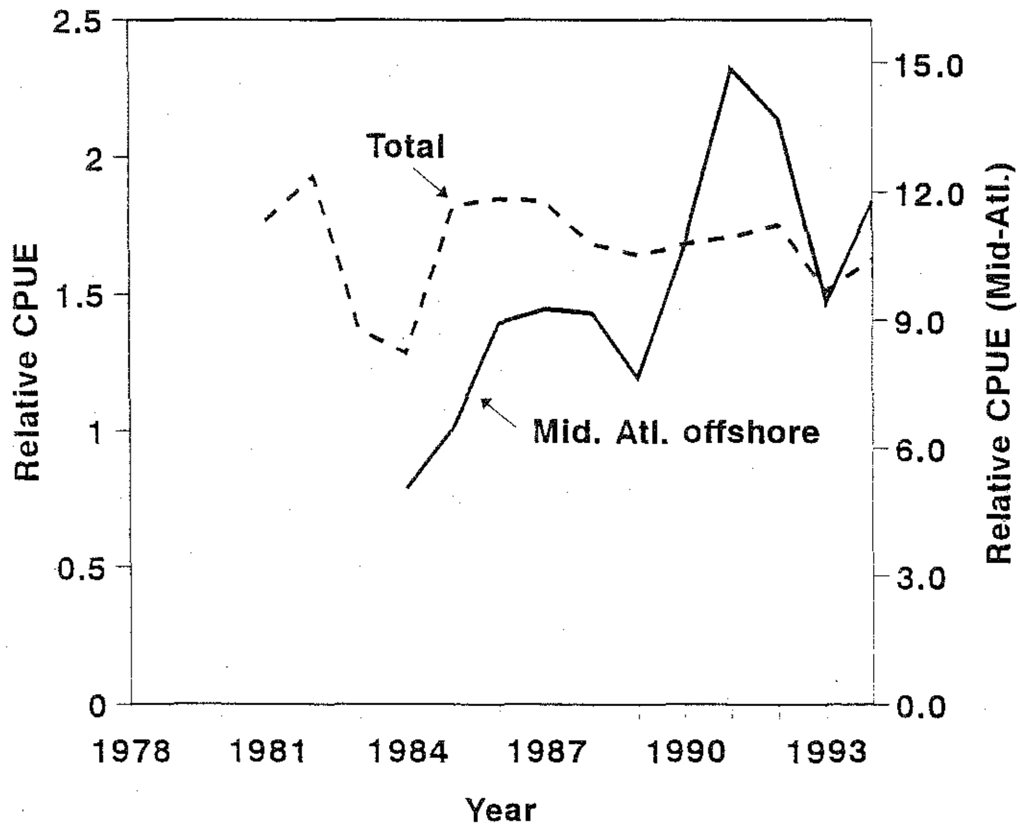

Figure 8. Mean catch per angler per trip from the MRFSS 1984-1994, standardized using a GLM. Mid-Atlantic data is mean catch per angler per trip for mid Atlantic party/charter fishery, 1984-1994.

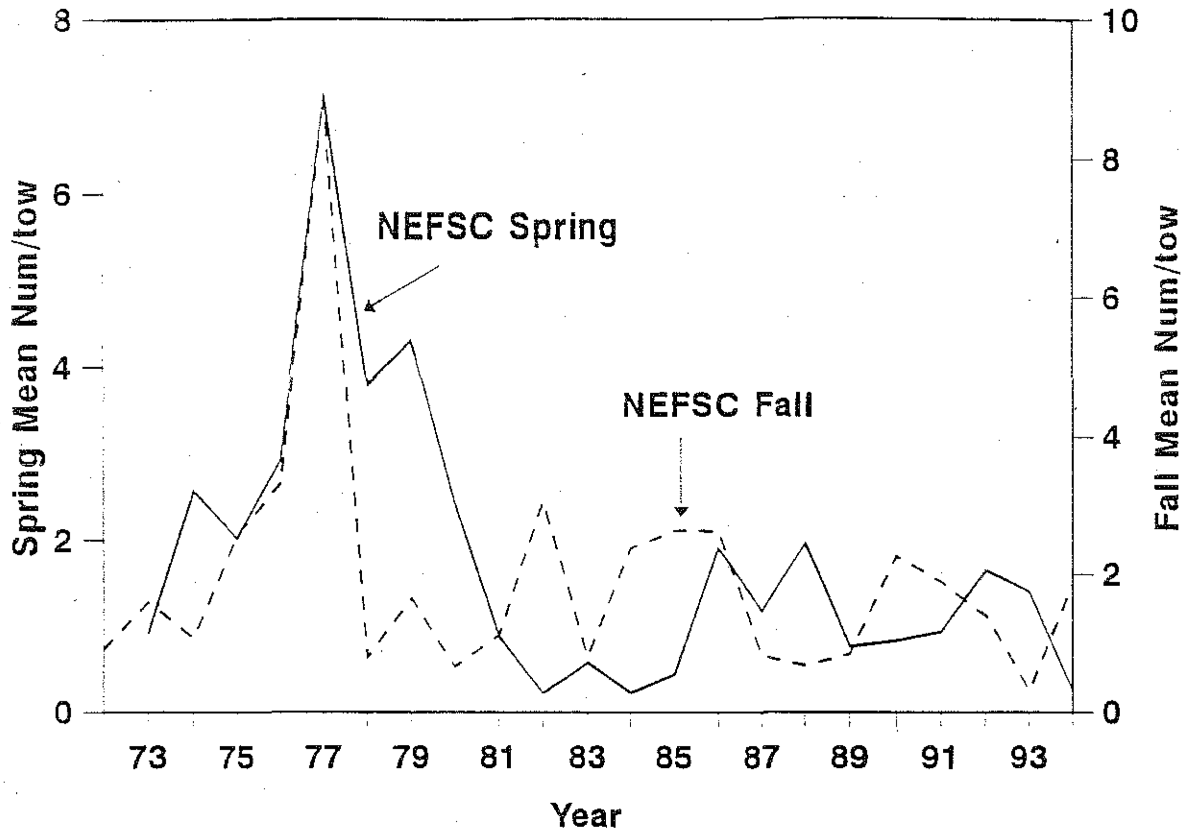

Figure 9. NMFS mean number per tow survey indices for spring and autumn bottom trawl surveys, Cape Hatteras to Cape Cod.

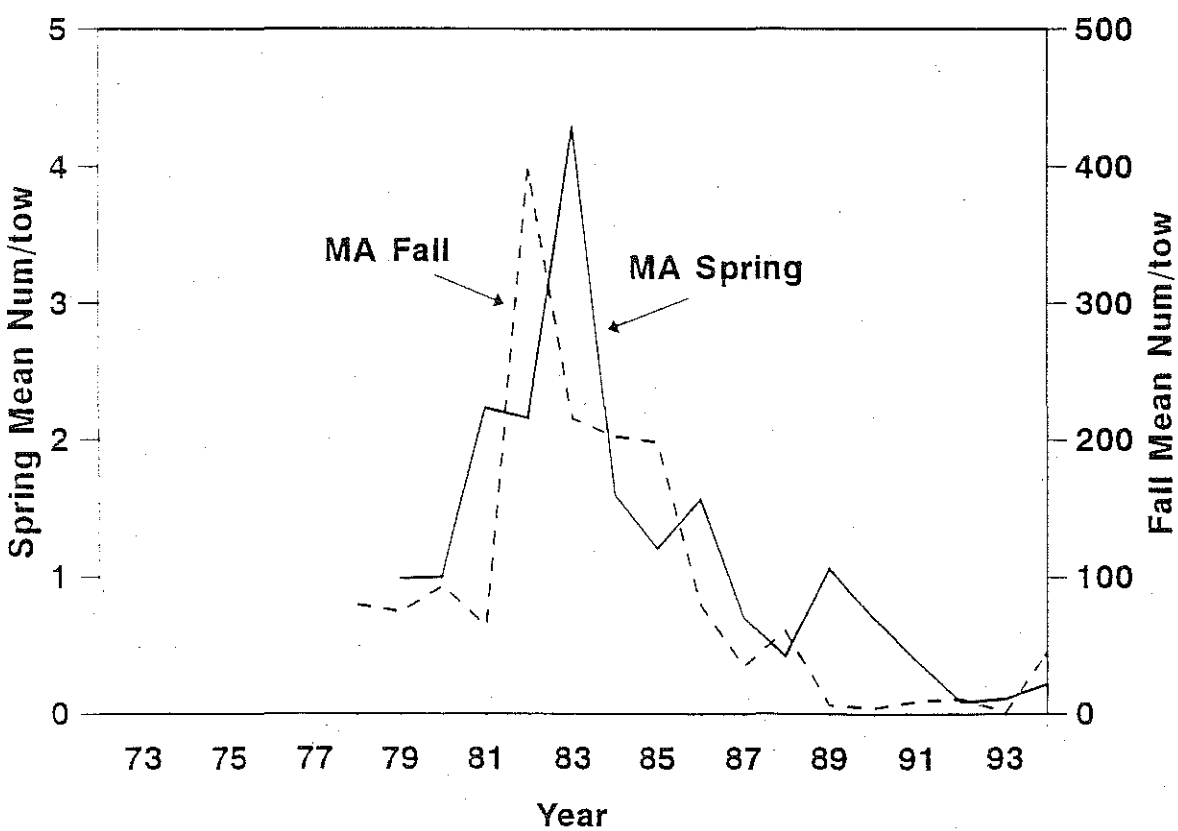

Figure 10. Mass Division of Marine Fisheries mean number per tow survey indices for spring and autumn bottom trawl surveys.

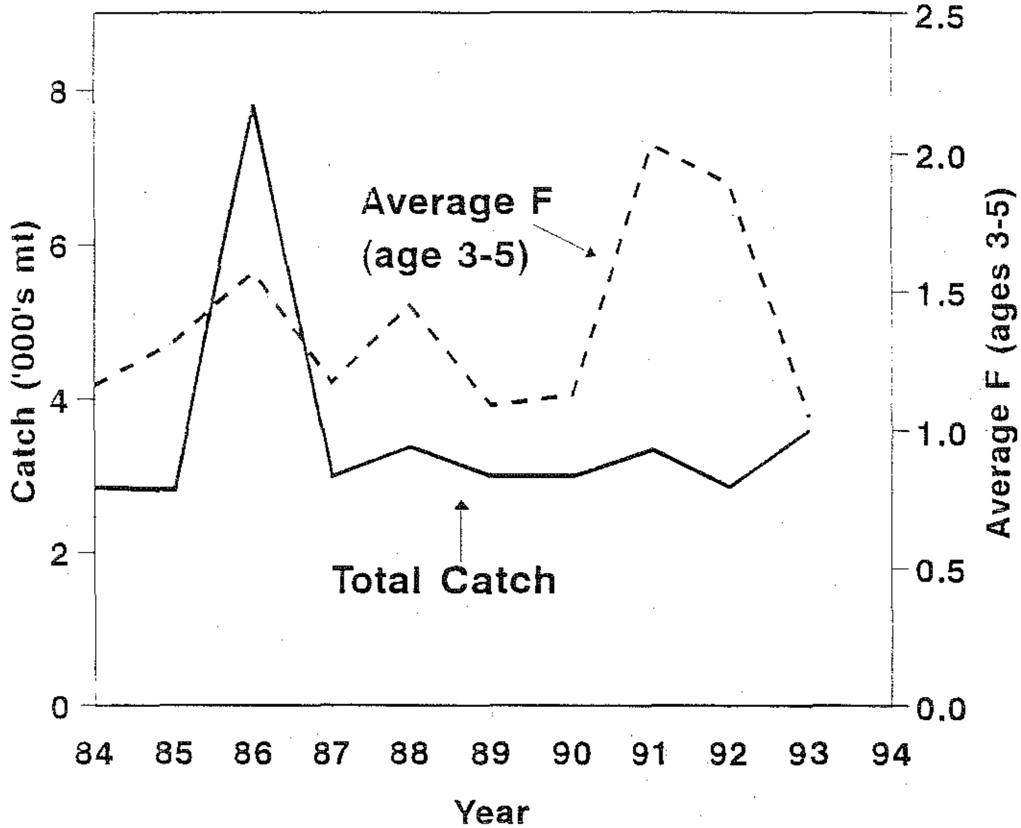

Figure 11. Average unweighted fishing mortality rates estimated from VPA analysis and associated total catch estimates.

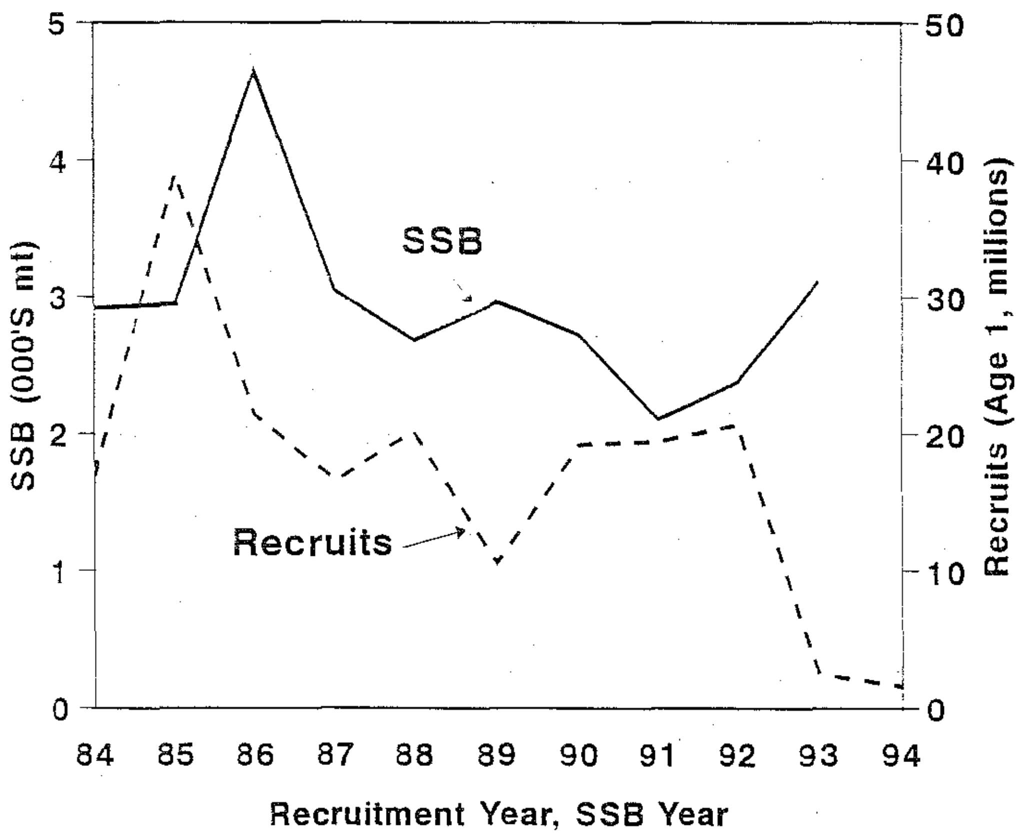

Figure 12. Estimates of annual recruitment and spawning stock biomass as estimated from the VPA analysis.

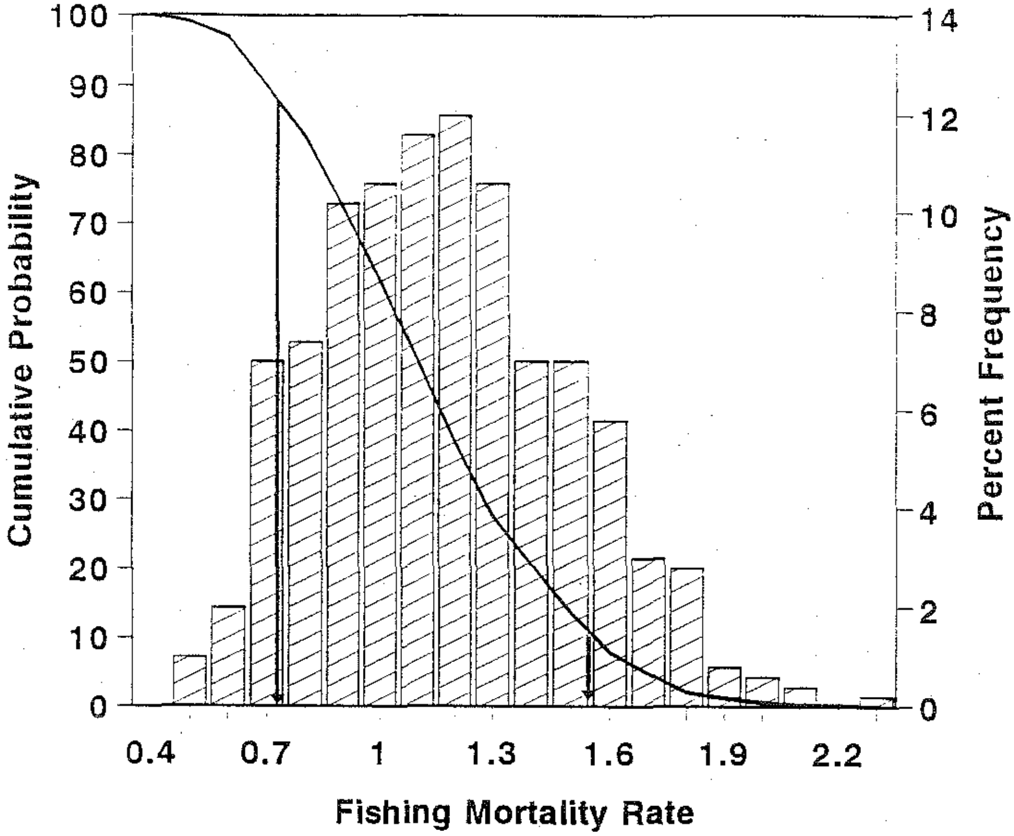

Figure 13. Bootstrap estimates of fishing mortality and the cumulative probability. Arrows indicate 10% and 90% probability levels.

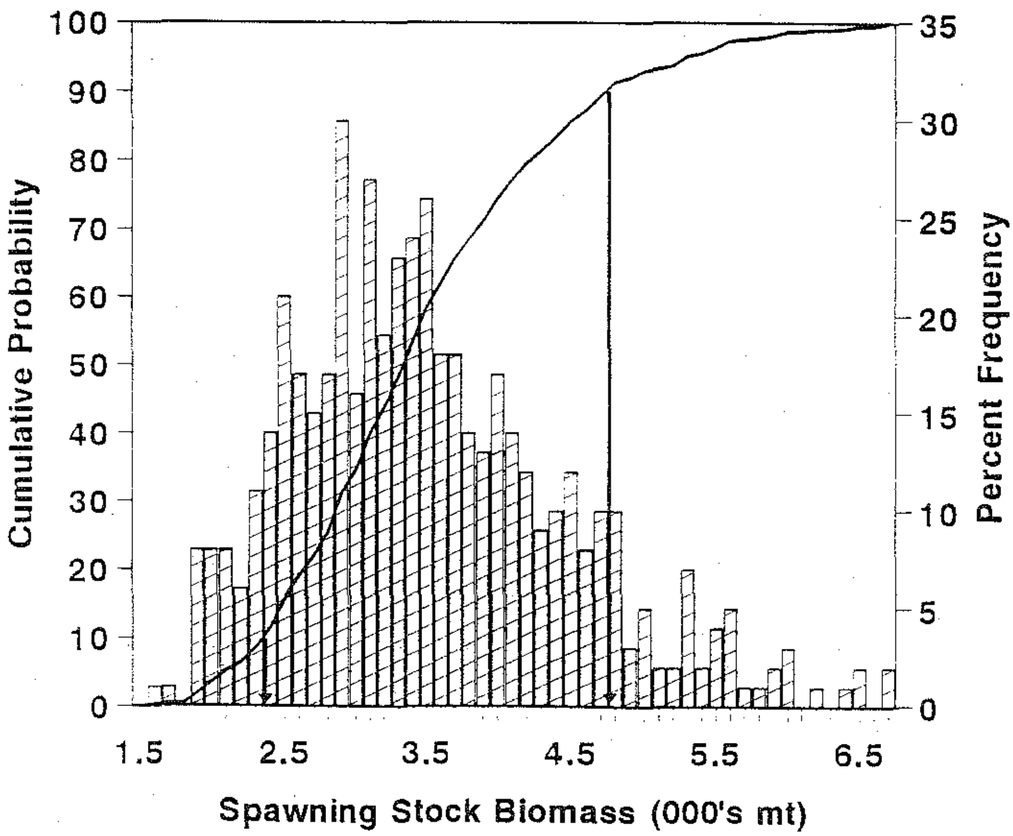

Figure 14. Bootstrap estimates of spawning stock biomass and cumulative probability. Arrows indicate 10% and 90% probability levels.