B. ATLANTIC BUTTERFISH

TERMS OF REFERENCE

1) Characterize the commercial catch including landings and discards.

2) Provide time series of survey catch (numbers and weight indices) for NMFS and appropriate state surveys.

3) Explore the influence of environmental factors on survey catch rates.

4) Conduct exploratory stock assessment modeling utilizing fishery catch and survey data sets.

5) If possible estimate fishing mortality, spawning stock biomass, and total stock biomass during the current year and characterize the uncertainty of those estimates.

6) Update, as appropriate, estimates of biological reference points.

INTRODUCTION

Butterfish (*Peprilus triacanthus*) are distributed from Florida to Nova Scotia, occasionally straying as far north as the Gulf of St Lawrence (Bigelow and Schroeder 2002). Butterfish are a fast growing species that undergo seasonal inshore and offshore movements. This schooling species seldom attains an age greater than 6 and often schools by size. Butterfish mature at age 1, spawn during the summer months (June-August), and begin schooling at about 60 mm (Bigelow and Schroeder 2002). They exhibit a planktivorous diet, feeding mainly on zooplankton, ctenophores, chaetognaths, euphasids. Butterfish are preyed upon by a large number of medium-sized predatory fishes such as bluefish, weakfish, and spiny dogfish; marine mammals such as pilot whales and common dolphins; seabirds such as greater shearwaters and northern gannets; and large pelagic fish such as swordfish, throughout their range.

The Mid Atlantic Fishery Management Council manages butterfish as part of the Atlantic mackerel, Squid, and Butterfish (MSB) Fishery Management Plan. Overfishing for this species is defined as occurring when Fmsy is exceeded, but an estimate of Fmsy is currently not available. The current overfishing definition is based on an MSY of 16,000 mt and a fishing rate of Fmsy. An MSY of 16,000 mt represents the current estimate of long-term potential catch for the stock and was used in previous amendments to the FMP. The target fishing rate for this stock is defined as 75% Fmsy which gives a target yield of 12,000 mt, well above the current quota specification of 5,900 mt. The biomass target for this stock is defined as Bmsy and the minimum biomass threshold is defined as ½ Bmsy. There have been a series of amendments to the MSB Fishery Management Plan; the most recent amendment (Amendment 9) does not propose any changes for butterfish.

The most recent assessment for this stock was completed in 1993 (SARC 17). Conclusions were that the stock was at a medium level of biomass and that catches were well below the MSY of 16,000 t. There was no information about exploitation rates available, but recruitment appeared to be at a high level.

Survey indices indicated a decline in 1992-93 from 1990 and adult stock had declined and was well below average.

THE FISHERY

Commercial Landings

Commercial landings by the United States have remained below about 5000 mt from 1960-2002 except for a period during the mid 1980s when landings increased to over 9,000 mt during 1982 and over 11,000 mt in 1984 (Table B1; Figure B1). Butterfish landings averaged 2,171 mt during 1965-1979 without any trend. During 1980-1989 landings increased sharply to over 9,000 mt in 1982, declined, and then increased to over 11,000 mt in 1984. This rapid increase in the 1980s occurred due to heavy demand for butterfish in the Japanese market. Demand waned and landings averaged only 2,790 mt during 1990-1999. More recently landings have declined markedly, averaging only 1,731 mt during 2000-2003, with very low totals in 2002 and 2003 (Table B1; Figure B1).

Reported foreign landings were much smaller than actual landings during 1965-1986 and were adjusted upward by Murawski and Waring (1979) for the years 1968-1976. . Adjusted landings from Murawski and Waring (1979) for 1968-1986 were used in the current assessment and the average ratio for adjusted landings (1968-1976; 1.437) was used to adjust reported foreign landings upward for the period 1977-1986. Since foreign landings were relatively small during this period only a small adjustment was necessary (Table B2).

Landings from the foreign fishery during 1965-1986 were relatively much larger than the USA fishery during this time, averaging over 6,800 t. Foreign landings varied from a low of 749 t in 1965 to 5,437 t in 1968 and increased the next year to 15,378 t. Foreign landings declined for a few years and peaked at 31,679 t in 1973, declining thereafter to a low of only 236 t in 1986 (Table B1).

Commercial Length Composition

Size composition from commercial samples of butterfish ranged between 12-25 cm during 1995-2003 with a modal length at 16-17 cm, depending on the year (Figure B2). The number of fish measured was higher during the earlier years, declining during 2000-2003 (Figure B2).

Commercial Fishery Discards

Previous assessments suggested that discarding of butterfish in the various fisheries might be a problem and recommendations by the SARC suggested that discards should be quantified if possible in future assessments. Several sources of information are available for the analyses of discards in the USA fishery. The vessel trip report (VTR) database, available since 1994, has been used to document discard rates and amounts in various assessments. Discard estimates from the VTR have not been used in assessments because it is felt that they underestimate the actual level of discards. Another source of information on discarding is the NMFS Observer program database. This source of information includes vessel trips with an observer on board the vessel with many if not most of the tows actually observed by the recorder. The general problem with this data has been the lack of a statistical design for sampling and the small number of trips that are actually covered in any given year. Previous to 1994 port agents interviewed vessel captains at the conclusion of the trip and estimates of discards for some stocks and areas fished were obtained and logged in a vessel trip file, but this source of information is no longer available.

Butterfish are caught in a variety of fisheries and may be retained or discarded depending on the particular demand in that fishery. Butterfish are often unwanted by-catch in many fisheries such as squid, silver hake, and mixed groundfish. Discards from these sources can be substantial and the total from all such fisheries can be large. To obtain information on the source of discards from various sources, several fisheries were defined based on a target species or mix of species (10 fisheries) and the percent and frequency of butterfish catches in those fisheries during 1989-2002 was calculated. Butterfish were caught frequently in the Fluke, squid, mixed groundfish, and silver hake fisheries (Table B2). These results of course varied by year and were often related to the demand for butterfish and also the other species during that particular year.

On an annual basis the fishery for squid produced the highest level of butterfish discards over the entire period (Table B3). Other important categories were mixed groundfish, Fluke, and Other. Discards in the silver hake target fishery were relatively large during 1989-1993, but declined considerably thereafter (Table B3).

Patterns in butterfish landings were examined by aggregating over a set of observed trips that caught butterfish during 1989-2003. The distribution of landings was highly skewed so upon examination of the data an arbitrary cutoff of 600 lbs was chosen to stratify butterfish trips for analysis (Figure B3). The distribution suggested that a large number of trips landed a small amount of butterfish and many fewer trips accounted for the largest landings.

Discard ratios were calculated using the VTR database for 1994-2002. Only trips that reported some discard of any species were used in the analysis. Initially all gears that captured butterfish were examined for discards, but only data for otter trawls were included in subsequent analyses because discards by other gears such as gill nets were negligible. The data were stratified into half-year intervals and two categories of landings, 600 lbs or less and greater than 600 lbs. An aggregate approach was used to allocate landings and discards into the appropriate categories, so that all trips with some amount of landings or discard were included in the analyses. Sample sizes in each cell were relatively large under this stratification scheme. Discard ratios were calculated by dividing discard by landings.

Results from this approach indicate that discard ratios averaged less than 1 for both categories of landings (Table B4). In many cases discard rates were very small on an annual basis indicating that reporting rates for discards in vessel logbooks may be relatively low. These results have been reported for others species in similar analyses of vessel logbook data. (NEFSC 2002). Therefore we did not use the VTR data to estimate discards in this assessment.

Another analysis was completed using the NMFS Observer database. Only data from observed tows were used in the analysis and only otter trawl trips were analyzed for the same reason as above. Data were stratified into half-year intervals and categories of 600 lbs or less and greater than 600 lbs. An aggregate approach including all trips with some landings or discard of butterfish was used to allocate trips into one of the four cells for each year during 1989-2002. Under this scheme since only observed trips were used, sample sizes were much smaller (Table B5).

Results showed that on average discard ratios were greater than 1 and in most cases significantly greater. With a few exceptions such as for some of the larger cells during 1997-2001, discard rates were greater than 1 (Table B5). Discard ratios in the 600 or less category during 1998-2002 were largest.

Since the data are skewed another, perhaps more appropriate analysis, using a log transformation, was completed. Only trips with matched landings and discard were used with the same four categories of season and trip size. The data were log transformed (ln(x+1)), and discard ratios were calculated on a per trip basis. Discard ratios were averaged in each cell and retransformed to the arithmetic scale. No correction for transformation bias was attempted since earlier studies indicated that variances were relatively high and the retransformed discard ratios would be too high to be useful (NEFSC 2002). It is likely that the backtransformed values are biased low so that discards are underestimated. Since only matched trips were used for this analysis fewer samples were available for this analysis, especially in the higher categories (Table B6).

Results from this approach produced discard ratios that were much less variable ranging from 0.47-4.61, and averaging 4.16 for <600 lbs and 1.67 for > 600 lbs (Table B6). These discard ratios were used along with otter trawl landings by half year and the same landings categories to estimate discards (tonnes) for each cell in each year and then totaled for the year. Discards ranged between 1,809-8,599 mt during 1989-2002 (Table B7). Discards were 4,442 mt in 1989, declined to 3,020 mt in 1990 and then increased steadily to 8,478 mt in 1993. After a decline to 3,701 mt in 1994, discards increased to 8,599 mt in 1995, followed by an almost steady decline to 2,427 mt in 2000 (Table B7). After increasing to 7,262 mt in 2001, discards declined to 1,809 mt in 2002.

Discards for1965-1988 were estimated by calculating an average discard ratio for each half year and landings category for 1989-2002. These average ratios were multiplied times otter trawl landings using the same stratification to produce an estimate of discard (tonnes) during 1965-1988. Discards were low, less than 2000 mt during 1965-1977 and increased markedly from the early to mid 1980s (Figure B4). Discards reached a peak in 1984 of 18,959 mt.

Size Composition of Discards

Data from observed otter trawl trips were assembled to examine the size composition of the discarded and kept fraction of trips where butterfish were caught. The size composition of discarded butterfish ranged form 4-24 cm depending on the year and the fishery, but discarded fish were generally less than 16 cm (Figure B5). The kept fraction of trips ranged from 10-22 cm and usually had a modal length from 16-18 cm (Figure B5). Sampling intensity was generally moderate to high during 1989-1991, low in 1992, and moderate from 1993-2000. Sampling intensity declined during 2001-2002, but may have increased in 2003 due to more trips being observed.

Total Catch

Landings from the USA, USA discards, and foreign landings during 1965-2002 were summed to estimate total catch over that period (Figure B6). Catches increased steadily from 1965-1973, reaching a peak of 34,265 mt in 1973. Catches declined after 1973 reaching about 7,200 mt in 1977 and then began another increasing period starting in 1979, reaching 31,500 mt in 1984 (Figure B6). After 1984 catches declined and stayed in a fairly steady pattern between 5,000 and 13,000 mt during 1987-2002. Recent catches have all been around 5,000 mt except during 2001 when the catch reached 11,700 mt (Figure B6).

RESEARCH SURVEY ABUNDANCE AND BIOMASS INDICES

Research survey abundance and biomass indices are available form several sources for assessing the status of the butterfish resource. Survey indices are available from NMFS surveys for the winter 1992-2002, Spring 1968-2002, and Autumn 1968-2002. The autumn period during 1963-1966 was not covered in the southern Mid-Atlantic Bight region so no indices are available for butterfish during this period. A new set of survey strata were used in this assessment because the set in the previous stock assessment included inshore strata 1-46 for the period 1968-1993. These inshore strata were not covered during 1968-1972 and were sporadically covered thereafter, so a set of offshore strata (1-14, 16,19,23,25,61-76) was used instead. Indices are also available for several state survey programs, notably Massachusetts DMF, Rhode Island DFW, Connecticut DEP, New Jersey BMF, and Virginia Institute of Marine Science (VIMS). The annual coverage for these surveys spans the period from 1978-2002 although some do not start until after 1978. In the short time available for this assessment, only data for the MA, RI, CT, and VIMS surveys were available, so only these surveys will be presented.

NEFSC Surveys

The NEFSC winter survey covers 1992-2002 with number per tow ranging from 38-169 and weight per tow from 0.8-6.2 (Table B8; Figure B7). With the exception of 1994-1995 and 2000 relative abundance has been moderate during this period and biomass has been moderate with a few low years (Table B8). The spring survey in number per tow ranged from a low of 9.9 to a high of 228 during 1968-1979, from 13.4-66.2 during 1980-1989, 8-9-112.9 during 1990-1999 and 36.8-61.2 for 2000-2002 (Table B8; Figure B7). Spring indices in wt/tow (kg) were generally higher in the early 1970s and early to mid 1980s than during the late 1980s and early 1990s (Table B8; Figure B8). Spring wt/tow (kg) indices increased slightly in the late 1990s and then declined again. Autumn survey indices in number/tow were generally much higher than the winter and spring indices because of the presence of the age 0 fish in the autumn. Catch per tow in number was moderately high but fluctuating during 1968-1978 and very high from 1979-1990 (Table B8; Figure B7). Indices declined slightly during 1991-2000 and then declined again in 2001-2002. Autumn indices in wt/tow (kg) were highest during 1979-1990, declining during 1991-1999 and then dropping to lower levels in 2001-2002 (Table B8; Figure B8).

Aged NEFSC Survey Indices

Aged butterfish survey data from NEFSC Spring and autumn surveys are available from 1982-2002. The delay difference biomass model used in this assessment is a partial age structured model, utilizing biomass per tow indices for two age groups, at age 0 and age 1+. Survey indices in both number and weight per tow (kg) at age were run to allow for the estimation of survey Z's and for use in the delay difference model.

Spring survey number-per-tow at age is shown in Table (B9). This survey generally catches age groups 1-3 and some fish from age group 4. Survey indices in number-per-tow at age for the autumn during

1982-2002 are shown in Table (B10). This survey generally catches age groups 0-3 with the age 0 catch dominating the total catch in number.

The autumn survey catch in weight per tow (kg) is shown in Table (B11) for age groups 0-3. Indices in weight for age 0 and aggregated 1+ for 1982-2002 were calculated from the table. Indices for 1968-2002 were calculated from the relative proportion of age 0's from Table E5 from the last assessment (NEFSC 1993). The relative proportions were applied to the catch/tow from the new strata set to get the numbers of 0's. These numbers were converted to weight (kg) by applying the average weight of an age 0 butterfish and then subtracting this wt from the total 1+ weight. The values for age 0 and 1+ were calculated for 1968-1981 and are shown in Table (B11).

Additional Survey Analyses

Several additional analyses were performed on the NEFSC spring and autumn survey time-series. Survey wt/tow indices were bootstrapped using the method of Smith (1997) to produce confidence intervals for spring and autumn during 1968-2002. Results indicate that both series have prominent confidence bands around their mean values (Figures B9;10). It also appears that the variance of the wt/tow values increases with increases in the mean. A plot for the autumn survey, showing the relationship between mean wt/tow and variance in mean wt/tow, confirms this (Figure B11). This is a common result, variance often increases as populations grow larger. The effect of stratification and sample allocation was also investigated. Results from this approach indicate that there were no persistent gains in efficiency for butterfish from the stratification scheme that is currently employed in the groundfish survey for spring and fall (Figure B12). This result is not surprising because the survey was not necessarily designed to sample species like butterfish. Depth, temperature, and day/night differences were also examined for possible links to the high variability in butterfish survey catches. No strong relationships were detected for either depth or temperature, but a reasonably strong relationship was indicated for day/night catches during the autumn. In most years survey wt/tow (kg)was higher during the daytime in the fall survey (Figure B13). There was very little difference in spring day/night catches. (Figure B13).

State Surveys

MADMF Survey

The Massachusetts survey during Autumn 1982-2002 was relatively flat from 1978-1991, and then increased considerably to a peak of 14.5 kg/tow in 1998, declining after that (Table B12; Figure B14). Survey catch rates from this survey are comparable to the NEFSC surveys.

RIDFW Survey

The Rhode Island survey covered the period from 1981-2002 with survey trends from 1981-1991 also being relatively flat (Table B12; Figure B14). Survey indices increased slightly to a peak of 9.3 kg/tow in 1997 and then declined to much lower levels after that. Survey catch per tow from this survey are about the same magnitude as the NMFS surveys although they cover a much smaller area.

CTDEP Survey

The Connecticut bottom trawl survey that was available had available indices in number/tow during 1984-2002. These indices were converted to wt/tow by multiplying by the average weight (0+) from the NMFS Autumn surveys for each year. Since this survey catches relatively large numbers of butterfish, the indices in weight are relatively large (Table B12; Figure B14). This survey shows a variable but increasing trend from 1984-2002.

VIMS Survey

The Virginia Institute of Marine Science bottom trawl survey in Chesapeake Bay catches a small number of age 0 butterfish during the autumn. This survey was available for the period from 1988-2001 and also was converted to a weight/tow index by applying the USA Autumn age 0 weight to each year. This survey shows a variable, but downward trend in biomass from 1988-2001 (Table B12; Figure B15).

Survey Indices for Scale

It is often necessary, especially for age-structured models, to constrain solutions to feasible regions so that useful results are produced. Several time-series were available for possible scaling of model results for the butterfish stock assessment. Murawski and Waring (1979) produced biomass estimates in a butterfish stock assessment (Figure B16). Minimum swept-area biomass estimates from the NEFSC Autumn survey were also prepared as a possible scale variable for the model. Waring (1970) used a ratio between day and total survey catch to produce a minimum biomass estimate for butterfish. The ratio of survey day catches (07:00-17:00) to total survey catch for each year in the autumn survey was computed. These ratios were averaged and each annual minimum biomass estimate was multiplied by this average ratio (1.54). Autumn survey minimum biomass tracks the autumn survey wt/tow index, but is scaled upward (Figure B17). The final series of data that are available is a set of autumn survey survival rates computed from the autumn survey number/tow indices. This index is calculated as a Heinke ratio between age 1+ in year t+1 and age 0+ in year t. These estimates are shown in Figure (B18).

BIOLOGICAL DATA AND ANALYSES

Growth

Starting in 1992 butterfish have been individually weighed while at sea during groundfish cruises. This database was used to fit Length-Weight equations for each year and each survey from 1992-2002. Plots of spring and Autumn LW relationships suggest that there were no changes in patterns of growth fro this species during this period (Figures B19; 20). On this basis common LW relationships were computed for spring and autumn as a weighted average of the a and b parameters for each year. These average LW parameters were used in SURVAN runs to produce mean wt/tow for 1982-2002.

We also needed to estimate Von-Bertalanffy growth parameters for use in the delay-difference model so we used an aggregate approach for all the data. Butterfish spawn during June-August and are assigned ages based on calendar years. Young-of-year butterfish born in the second half of 1983, for example, reach *nominal* age 1 on January 1, 1984 at a *biological* age of no more than 6 months. Butterfish grow rapidly and significant numbers are taken in commercial fisheries at nominal age zero as bycatch primarily during the second half of the year. Age data given in this report are nominal ages (as assigned by readers) unless otherwise specified.

The KLAMZ (FPA) model for butterfish was set up on a calendar year basis using nominal ages. In the model, new recruits are age 0 butterfish that recruit to the stock on January 1. Estimates of total biomass (ages 0+) on January 1 from the FPA model for butterfish are hypothetical figures that include the amount of hypothetical age zero biomass necessary (considering growth and mortality) to explain subsequent catch data and survey trend data. To avoid using hypothetical biomass levels, it is probably better to track butterfish population dynamics in terms of average annual total biomass (ages 0+ at some point mid-year) or escapement biomass (ages 1+ on January 1) which are also estimated in the FPA model. Approaches to modeling growth and population dynamics for species like butterfish that recruit at age zero and grow quickly is a topic for future research.

Butterfish in NEFSC fall and spring surveys have been individually weighed at sea since 1992. A length-weight relationship was estimated based on all available length and individual weight data (see below).

```
       *** Nonlinear Regression Model ***

Formula: INDWT ~ alpha * LENGTH^beta

Parameters:
            Value   Std. Error  t value
alpha 0.0000158953 3.50244e-007  45.3836
 beta 3.0854500000 7.90770e-003 390.1830

Residual standard error: 0.00771297 on 11552 degrees of freedom

Correlation of Parameter Estimates:
      alpha
beta -0.998
```

The estimated length-weight parameters were used to calculate individual body weights for all butterfish taken in spring, fall and winter surveys and aged since 1963. Records for eleven age 0 butterfish from winter and spring surveys were omitted because age 0 butterfish should not be available until after June. Data from a total of 21,765 butterfish ages 0.78-6.3 years were used to estimate growth curves (Figure B21).

The average Julian date of survey tows in butterfish strata for spring surveys during 1968-2002 was 95 days and the average Julian date for fall surveys was 284 days. Therefore, ages used in fitting growth models were adjusted by increasing the nominal age by 95/365=0.26 y for butterfish taken in spring surveys, by 47/365=0.13 y in winter surveys, and by 284/365=0.78 y for butterfish taken in fall surveys (see below).

Schnute's (1985) general growth model used in derivation of the delay difference model in FPA is:

$$w_a = v + (V - v)\frac{1-\rho^{1+a-k}}{1-\rho}$$

where k is the age at recruitment, w_a is weight at age $a \geq k$, v is the predicted value of w_{k-1}, V is the predicted value of w_k, and $\rho=e^{-K}$ where K is the parameter for von Bertalanffy growth in weight. The FPA model, in turn, uses the growth parameters ρ and $J=v/V$.

Modeling butterfish growth in the FPA model is complicated by the differences between nominal age (based on calendar years used in the model) and biological age, and because recruitment occurs at age zero and growth is rapid. As shown above, the growth parameter v should be a positive number that estimates body weight at age k-1 one year prior to recruitment. In theory, the parameter v for butterfish would be body size at age k-1 = –1 during the January of the year before spawning occurs. Moreover v for butterfish is negative when $k = 0$ (see below).

To obtain useful growth parameters for modeling butterfish, we estimated growth parameters in Schnute's model by nonlinear regression assuming that butterfish recruit at a nominal age of 1.5 in nominal years (age 1 in biological years). Results (see below) were statistically significant although butterfish growth is highly variable. Growth parameters used in the FPA model for butterfish were ρ=0.81605800 and J=v/V=0.09675675 (see below).

```
    *** Nonlinear Regression Model ***

Formula: calcwt ~ schnute(newage, littlev, bigv, rho, k = 1.5)

Parameters:
             Value  Std. Error  t value
littlev 0.00507862 0.000375370  13.5296
   bigv 0.05248860 0.000230723 227.4960
    rho 0.81605800 0.009812100  83.1685

Residual standard error: 0.0229647 on 21762 degrees of freedom

Correlation of Parameter Estimates:
     littlev   bigv
bigv -0.318
 rho  0.729  -0.728
```

Our approach to estimating growth parameters may underestimate the growth rate and biological productivity of age zero butterfish in the FPA model. Nevertheless, the parameter J=0.09675675 implies that body weight of young-of-year butterfish increases quickly by about 1/J=10.3 times per year during the first year of life. In addition, growth curve predicted weights for age zero butterfish during the second half of the year (when age zero butterfish tend to be taken by the fishery) and weight at age for all subsequent ages appears reasonable (see below).

For potential future use, we fit a conventional von Bertalanffy growth model using nonlinear regression and the same data (see below). As expected (Schnute 1985), the resulting von Bertalanffy growth curve was indistinguishable from the Schnute growth curve.

```
    *** Nonlinear Regression Model ***

Formula: calcwt ~ vb(newage, winf, vbk, tzero)

Parameters:
         Value Std. Error t value
 winf 0.262838 0.01167340 22.5160
  vbk 0.203254 0.01202370 16.9045
tzero 0.403999 0.00840727 48.0535

Residual standard error: 0.0229647 on 21762 degrees of freedom

Correlation of Parameter Estimates:
        winf    vbk
  vbk -0.996
tzero -0.742  0.787
```

Natural Mortality

Natural mortality rates for butterfish were investigated in Murawski and Waring (1979). The best estimate from this study was M=0.8, and this value was also used in the present stock assessment. Other supporting evidence suggests that natural mortality rates for this species may be high. Overholtz and Link (2000) studied consumption of pelagic fishes and squids in the Northeast shelf ecosystem. This study suggested that butterfish were not only important in the diets of predatory fish in the region in general, but that during 1977-1997 butterfish may have been very important to predators during years when herring and mackerel biomass was low. Consumption by predators as a group and as individual species was certainly important during this time. For example, a significant amount of butterfish is consumed by weakfish, spiny dogfish, and silver hake (Figures B22-24).

ESTIMATES OF MORTALITY AND STOCK SIZE

Total Instantaneous Mortality from Surveys.

Total mortality rates (Z) were estimated from both spring and autumn bottom trawl survey number/tow at age data from 1982-2002 assuming all age groups were equally available to NEFSC survey gear. Since total mortality is so high over each age group for butterfish, it is possible to estimate age specific values rather than the traditional Heinke aggregated estimate. Survey Z's were very high in the Spring survey, ranging from 0.451-3.65 for age 1, 0.381-3.965 for age 2 and averaging greater than 1.7 for ages 1-2 (Table B13). Estimates for age 3 ranged form .096-4.673, averaging almost 3.0 (Figure B13). Survey Z's followed a similar pattern for the autumn survey. Estimates of Z ranged from 0.822-4.139 for age 0, .0689-3.294 for age 2, averaging 1.789 for age 1 and 1.487 for age 2 (Table B14). Estimates for age 3 ranged from 1.296-6.332, averaging 2.335. These total mortality rates indicate that few butterfish survive beyond age 4 in the spring.

Survey Exploitation Rate Index

Survey exploitation rate indices were calculated by dividing annual butterfish catch by survey indices for spring and autumn. These indices were calculated by using the spring age 1+ wt/tow indices and the autumn age 0+ wt/tow indices for 1968-2002.

The spring exploitation index is variable, but relatively flat over the period (Figure B25). There is some indication that exploitation rates have dropped in the more recent years from 1997-2002. The autumn exploitation index is also variable, but appears to have declined over time through 1990 (Figure B26). More recently, the index is again variable, increasing to a higher point in 1996 and 2001, but otherwise less than half of some of the values observed in the late 1960s and early 1970s.

An Index Method (AIM)

An Index Method (AIM), part of the Woods Hole Toolbox modeling package, provides a more formal method for investigating the relationship between catch and survey indices than the simple exploitation index method. AIM allows for an investigation of the relationship based on a statistical fitting procedure and for the estimation of a replacement level of F to serve as a reference point for a stock. Butterfish catch and spring and autumn survey indices in wt/tow for 1968-2002 were used in the method to discover if any useful signal was present in these data. Auto-correlation analysis indicated that several significant lags were present between the replacement ratios and the relative F's for butterfish from both the surveys and especially the fall (Figure B27). Randomization tests indicated that this relationship was not significant for both surveys. The relationship between relative F and replacement ratio was reasonably good for the spring and the relative F was estimated as F=6.06 (Figure B28). The bootstrap distribution of relative F was fairly broad with an 80% confidence interval between 4.98-7.26 (Figure B28). The relationship between relative F and replacement ratio was somewhat poorer for the fall with the replacement F estimated as 1.50 (Figure B29). The bootstrap distribution of relative F was tighter than the spring with and 80% confidence band between 1.02-2.01 (Figure B29). The six-panel plot for the spring suggests that replacement ratios have been variable over time, and the current relative F is below the replacement F (Figure B30). The corresponding plot for the fall suggests that the replacement ratio has declined steadily over time and the current relative F is slightly above the replacement F (figure B31).

Forward Projection Analysis (FPA) Description

Details of the FPA approach are provided in Appendix A1 (Ocean quahogs). The analysis starts in 1965 and projects forward through 2002. Total biomass, average biomass, recruitment biomass, fishing mortality, and surplus production are estimated in the model.

Growth

Growth is modeled as a Von-Bertalanffy process with k=0.2033 and a constant J ratio of J=0.09677 for 1965-2002.

Maturity

Maturity was assumed to be 0 at age 0 and 1 for age 1+ butterfish.

Natural Mortality

Natural mortality was assumed to be 0.8 as in previous assessments. The FPA allows for the estimation of annual changes in M by modeling it as deviations from a mean value (see appendix A1), but this feature was not used in the current approach.

Recruitment

Recruitment can be modeled in several ways in the FPA. A Beverton-Holt stock-recruitment model was used to model recruitment with the alpha and beta parameters estimated internally in the model (see appendix A1 for details). This formulation was used in initial model runs, but was not used in the final model formulation. The final model estimated recruitment biomass as deviations around the mean recruit biomass during 1965-2002.

Surplus Production

Surplus production for the butterfish stock was estimated with an external Fox (1975) model fit to surplus production and average biomass estimates (Jacobson et al. 2002).. Parameters were estimated internally and lambda was set at 0.0001. This allows the parameters to be estimated, but not influence the model fit to any appreciable degree.

Catch

The total estimated catch (Figure B6) including components for landings and discards was used in the FPA model.

Research Surveys for Trend

The four NMFS surveys were used to tune the butterfish FPA model. These surveys included a Winter 1+ survey, a Spring 1+ survey, an autumn age 0 survey, and an Autumn 1+ survey. The four state surveys were added to the model formulation, but due to time constraints and unresolved residual patterns they were not used in final model runs. This however, does not preclude their use in future modeling exercises for butterfish.

Time-Series for Scale

Three time-series were available for scaling model results in the FPA runs. The biomass estimates from Murawski and Waring (1979) for 1968-1976 (Figure B16), the minimum swept area biomass estimates for the autumn survey for 1968-2002 (Figure B17), and the survey survival rates (S) for the autumn survey 1982-2002 (Figure B18). Although these scalar series were not used in the final model run, they were very useful in profile analyses for determining the best overall model.

Survey Covariates

We hypothesized that the inclusion of the polyvalent doors in 1985 may have affected the catch of butterfish in the spring and autumn surveys. The coefficient for weight per tow for butterfish was not significant (p=.866) (Byrne and Forrester 1991) from the door conversion experiments that were conducted. However, the experiments were not designed to estimate the effects of the door change on pelagic fishes such as butterfish and herring. So, we used a covariate for the door conversion for butterfish; an indicator variable approach was chosen for introducing this variable to the likelihood function as:

$$q' = qe^{\delta D}$$

Where δ is the estimated parameter and D is 1 during 1985-2002 and 0 for all other years in the spring and autumn surveys. Door parameters for the spring and Fall 1+ were examined and found to not be significant and therefore were not included in the final model. A door parameter for the fall age 0 was retained because it was significant and the adjustment in catchability that was predicted was in the correct direction (Figure B32).

We also added a covariate for the change in gear that took place in the spring survey during 1977-1981. In gear comparison studies on the difference between the 36 and 41 trawl; the 41 net caught significantly more butterfish (p=0.05) (Sissenwine and Bowman 1978). This covariate was also added as an indicator variable. The parameter for Spring1+ net was significant and the adjustment for the change to the 41 net was also in the correct direction (Figure B33). The addition of these two survey covariates improved the model fits and residual patterns for the spring age 1+ and especially for the fall age 0 surveys.

FPA RESULTS

Profile and Sensitivity Analysis Results

A series of profile and sensitivity runs were completed to narrow model choices to a few candidates for a final model. Choices included an unconstrained run, runs constrained to particular values of q for Survey Survival (S) and runs that allowed catch to be estimated. The Working Group felt that a profile run over M would also be useful. Values of emphasis coefficients (lamda's) that were used to accomplished these various runs are listed in Table (B15).

Natural Mortality

Since the assumed natural mortality rate in the FPA model for butterfish is very high (M=0.8), a profile analysis was completed to decide if this rate is reasonable. The model was run in increments of M of 0.1, from 0.6-1.4. Results show that the model fits, based on total survey likelihood (Surveys-All) and total likelihood (Total Log Likelihood) were better for values of M of 0.8 or greater (Table B16). When M was reduced below 0.8, the total negative log likelihood increased rapidly. The Working Group concluded that a value for M of 0.8 was reasonable for modelling the butterfish stock.

Survey Survival Rates

One important time-series of information available for scaling model results are survey survival rates (S) (Figure B18). The model was run by placing a large emphasis coefficient (lambda) on q (q=10000) for survival rates and completing a series of model runs. The q for Survival rate parameter was incremented by 0.1 from q=0.2-1.0 and survey covariates for net and doors were switched on. Likelihood terms for the total survey likelihood (Survey_trends), individual surveys (for example Trend_Winter.Survey.Age.1+) and the total likelihood (Total_LogLikelihood) were examined. Values for MSY, Bmsy, average biomass during 2000-2002 (av biomass last 3 yrs) and average F (av F last 3 yrs) were also scrutinized by the Working Group. There is a pronounced bottom in both total survey and total likelihood at a q=0.4 (Table B17). Values of MSY, Bmsy etc are also infeasible at q's < 0.4, and total likelihood increases beyond a q of 0.4. On this basis the Working group concluded that a model run using unconstrained results (q=0.446) would be a possible candidate for a final model.

Estimation of Catches

The Working Group also wanted to examine a set of model runs that allowed for the assumption that catch is measured without error to be relaxed. Since discards are such an important component of the catch in the butterfish assessment, this is a very important issue to resolve. A sensitivity analysis was conducted on the coefficient of variation (CV) of catch to determine the best model and appropriate CV to use if catch is estimated. The model was stepped through CV's of 0.1-0.5 in 0.1 increments and survey covariates for net and doors were switched on.

The model had trouble converging at CV's greater than 0.3, giving infeasible results (Table B18). After examining the feasible runs between 0.1-0.3, the Working Group concluded that a model run with a CV=0.1 was the best case for an overall model that estimates catches with some error. This model was chosen based on the catch likelihood term (0.259), and its relative stability for biomass and F. When trends in average biomass and fishing mortality were examined, runs with CV's greater than 0.1 were rejected (Figures B34; 55).

The Working Group also looked at a sensitivity run for catch CV's with the survey covariates switched off. The total likelihood was much larger for these runs indicating that including these covariates provided for better model fits. Model goodness of fit measures are better as well as residual patterns for model formulations with the survey covariates for net and doors included.

Final Model

Model outputs for the no constraints case and the catch CV=0.1 case are very similar (Table B19). The Working Group decided that the model that estimated catch with some error was a better choice than the model scaled to survey survival rates (S) because discards play a major role in this assessment. However, although initial runs for the catch estimation model converged, later runs with average biomass, spawning biomass, and recruitment did not converge. Therefore, the SARC decided to accept the unconstrained run as the final model (Table B19). Values of lamda's used in the final model run are shown in Table (B20). Parameter values estimated in the final model run are shown in Table (B21).

Average Biomass

Average biomass was variable during 1968-2002, reaching numerous short-term peaks and lows during the period (Figure B36). Average biomass ranged between 7,817-77,189 mt and averaged 33,399 mt during this period (Figure B36). Average total biomass during 2000-2002 was 18,714 mt and 7,817 mt in 2002.

Spawning Biomass

Spawning biomass was also variable during 1968-2002 reaching several periodic peaks and lows during this period (Figure B37). Spawning biomass ranged between 7,843-62,914 mt and averaged 23,239 mt during this period (Figure B37). Spawning biomass averaged 19,100 mt during 2000-2002 and was 8,681 mt in 2002.

Fishing Mortality

Fishing mortality was relatively high during 1968-1976, dropping after that to an average of about 0.3 during 1977-2002 (Figure B38). Fishing rates were more variable recently, from a low of 0.12 in 2000 to a high of 0.70 in 2001 (Figure B38). The average fishing rate during 2000-2002 was 0.39 and F in 2002 was 0.34..

Stock Recruitment-Recruitment Biomass

Recruitment biomass has been highly variable for the butterfish stock over a range of spawning biomass between about 10,000-50,000 t (Figure B39). Recruitment biomass ranged between 2,812-61,062 mt during 1968-2002 and averaged 23,179 mt (Figure B40). The recent average was 7,988 mt and recruitment biomass in 2002 was 2,974 mt (Figure B40). Recent recruitment has been below average and recruitment in 2001 and 2002 are among the lowest in the series.

Surplus Production

Surplus production was estimated with an asymmetric Fox (1975) model. Reference points for this model were MSY=12,175 mt, Bmsy=22,798 mt and Fmsy=0.38 (Figure B41).

Loss to Natural Mortality

For many fish stocks it is common for landings to greatly exceed losses to natural mortality, not so for pelagic species. Natural mortality rates are generally higher, hence a much larger fraction of the stock is removed by natural causes, usually predation, but disease and other causes can be important. Since this component of total mortality can be important for butterfish, it is worth quantifying this loss. Biomass lost to M ranged from 5,237-42,323 mt and averaged 21,382 mt during 1968-2002 (Figure B42). This metric is useful for understanding the large fluctuations in biomass and relatively low surplus production for this stock.

Precision of FPA Estimates

The relative precision of the estimates for average biomass and fishing mortality and their 80% confidence intervals were calculated using a bootstrap procedure. One thousand bootstrap runs were completed and the results were summarized in frequency and cumulative distribution plots. Results indicate that estimates for both average biomass and F are relatively imprecise. Estimates for average biomass ranged from 655-49,127 mt with an 80% CI between 2,606-10,874 mt (Figure B43). Estimates for F ranged from 0.055-4.08 with an 80% CI between 0.246-1.03 (Figure B44). Although the percent of bias was not specifically estimated, results suggest that average biomass was biased low and F was biased high.

Model Diagnostics

Plots of survey residuals for the four NEFSC surveys used to tune the FPA model for trend were produced as a diagnostic measure of goodness of fit. Plots of observed vs. predicted data series and residual trajectories (residuals vs. time), and residuals vs. predicted values were produced and are shown in Figure (B45).

SARC COMMENTS

The SARC discussed the methods used for estimating discards. Discards were estimated as a significant proportion of the total catch (about 2/3 of the total catch since 1980). Examination of alternative stratification of the discard data should be made in future assessments. Stratification by target species and/or combining data temporally to increase the sample size may provide better discard estimates. Variance estimates of discard ratios can be used as a diagnostic for determining the reliability of the estimates. A plot of estimated ratios revealed little trend over time and suggested that time averaging of the ratio may be appropriate. Statistical tests between the stratified discard estimates should be made to justify the stratification used. The discard estimate should be considered a minimum estimate of discards since the estimate was limited to observer trips, which possessed both, landed and discards of butterfish. The SARC noted that the high 1995 discard ratio was primarily due to several trips, which landed a relatively small amount of butterfish landings. Although there is uncertainty in the discard estimates the SARC felt the scale of the discards is clear. The SARC accepted the use of the discard estimates for the assessment while recommending further investigation on discards be done in future assessments.

The SARC reviewed an index method (AIM) for assessing butterfish. The SARC noted the relatively weak correlation between the replacement ratio and the relative F in the model and questioned the utility of the model for this species. It was suggested that limiting the survey index to fully recruited fish (omitting age 0 fish in the Fall survey) might result in a better relationship between the biomass index and the rate of removals by the fishery.

The SARC reviewed a delay-difference model for butterfish. A profile on natural mortality suggests an improvement in model fit as M increases, indicating that M was not estimable. The SARC suggested exploring alternative methods for estimating natural mortality external from the model. Given the uncertainty in estimated discards it was thought that a model with estimation of catch with error is warranted. However, a profile on changes in the assumed CV on catch (estimated with error) estimated Qs for adjusted biomass, which were biologically unrealistic (>1). Questions on the proportion of the stock coverage by the survey and day night differences in catch should result in a lower estimate of Q in the absence of herding.

It was noted that very similar fits to the data exist in the final set of model runs but these runs produced very different stock status determinations. The SARC questioned whether the number of parameters in the model allows for alternative states of nature to be fit equally well particularly with a species that possesses large fluctuations in the survey indices. The SARC requested that the diagnostics for using survey covariates be included in the document. It was noted that the final model run proposed by the working group does produce estimates of average biomass in the last three years which match the estimates of Fall minimum swept area biomass. The SARC noted a lack of coherence between the spring and fall survey by age (0 and 1+).

The SARC requested a table of estimated model parameters and CVs. The lack of convergence for the model run, which estimated catch with error, deemed this run as unreliable. The SARC noted that the estimated net covariate parameter from the model was very similar to the published Yankee 44 net conversion factor. However the SARC felt the door covariates parameters where not significant and should be omitted in the final run. The SARC concluded that the status determination of the stock should be made by using the ratios of the point estimates to the reference point.

SOURCES OF UNCERTAINTY

1) The estimate of natural mortality is uncertain.

2) Observer sampling of the trawl fishery has been low and increases the uncertainty of the discard estimates.

3) The lack of coherence between the spring and fall surveys is a source of uncertainty.

4) The new model based estimates of biological reference points are uncertain

RESEARCH RECOMMENDATIONS

1) A study of the characteristics of inshore and offshore components should be initiated. A study of growth, morphometrics, distribution and other factors related to inshore and offshore butterfish should be conducted.

2) Further work on potential information (for example the VTR database) for the estimation of discards of butterfish from all sources should be undertaken. Other methods and stratification and time averaging of the discard data for estimating discards should be explored.

3) A close examination of the NMFS Observer data from 2003 was warranted for its application in the next butterfish assessment. Observer coverage was transferred to only a few vessels in the Illex fishery and hence was greatly expanded because of the transfer of effort into the scallop fishery by large Mid-Atlantic trawlers.

4) Explore alternative methods for estimating natural mortality.

5) Explore using landings of target species as a denominator in the discard ratio, based on VTR matched trips (trips with reported landings of target species and butterfish discards).

6) Explore the utility of incorporating into the assessment model ecological relationships, predation, and oceanic events that influence butterfish population size on the continental shelf and its availability to the resource survey.

7) Explore the use of an age-based model for future assessments.

8) Further investigate the estimation of suitable biological reference points. Stock status determination is currently based on an Fmsy proxy (F0.1=1.01, Bmsy has not been previously estimated). New biological reference points were estimated in the delay-difference model for butterfish. However, there is considerable uncertainty in these estimates and they are subject to change

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Table B1. Butterfish USA landings (tonnes), USA discards, Foreign landings, and total catch during 1965-2002

Year	USA landings	USA discards	Foreign landings	Total catch
1965	3340	833	749	4922
1966	2615	846	3865	7326
1967	2452	991	2316	5759
1968	1804	770	5437	8011
1969	2438	968	15378	18784
1970	1869	569	12450	14888
1971	1570	866	8913	11349
1972	819	293	12221	13333
1973	1557	1030	31679	34266
1974	2528	1409	15465	19402
1975	2088	1478	12764	16330
1976	1528	969	14309	16806
1977	1448	1172	4607	7228
1978	3676	5237	1906	10819
1979	2831	3452	1207	7491
1980	5356	7802	1264	14422
1981	4855	7412	1345	13612
1982	9060	12906	907	22873
1983	4905	6421	906	12231
1984	11972	18959	617	31547
1985	4739	7134	1156	13029
1986	4418	7249	236	11902
1987	4508	7168		11676
1988	2001	3224		5225
1989	3203	4442		7645
1990	2295	3020		5315
1991	2149	3451		5600
1992	2752	5698		8450
1993	4604	8478		13082
1994	3631	3701		7332
1995	2080	8599		10679
1996	3547	6823		10370
1997	2784	3852		6636
1998	1956	3274		5230
1999	2103	4115		6218
2000	1422	2427		3849
2001	4396	7262		11658
2002	867	1809		2676

Table B2. Observed tows with butterfish catch for target species or groups including target, number of trips, percent trips, cumulative frequency of trips, and cumulative percent of trips from the USA observer program database during 1989-2003.

Target	Frequency	Percent	Cumulative F	Cumulative P
None	206	3.7	206	3.7
Scup	83	1.5	289	5.2
Fluke	818	14.6	1107	19.8
Other	971	17.3	2078	37.1
Squid	2120	37.9	4198	75.0
Butter	233	4.2	4431	79.1
Finfish	136	2.4	4567	81.6
Mix Flnd	21	0.4	4588	81.9
Mix Grnd	391	7.0	4979	88.9
Silver Hake	620	11.1	5599	100.0

Table B3. Target species or group, number of trips, landings (kg), and discards (kg) during 1989-1993.

Year	Target	Trips	Landings	Discard
1989	None	7	8996	8333
	Scup	2	640	315
	Fluke	12	294	679
	Other	12	3996	6316
	Squid	11	6016	10691
	Finfish	2	75	625
	Mix groundfish	13	10592	1387
	Silver hake	20	8960	21660
1990	None	1	53	565
	Fluke	11	1096	684
	Other	15	1209	2139
	Squid	11	9561	3750
	Finfish	8	4251	3861
	Mix flounder	2	2	2
	Mix groundfish	5	1870	2716
	Silver hake	11	618	239
1991	None	9	3832	13052
	Fluke	11	77	3623
	Other	24	34277	21549
	Squid	25	6432	45113
	Butter	6	45622	8574
	Finfish	6	806	9389
	Mix flounder	3	51	176
	Mix groundfish	17	10142	19043
	Silver hake	21	3308	5708
1992	None	1	1149	4502
	Fluke	23	1491	7795
	Other	9	267	5602
	Squid	11	7133	31467
	Finfish	2	15	22
	Mix groundfish	20	10429	58545
	Silver hake	13	1661	1208
1993	Fluke	8	1274	4000
	Other	7	2731	19417
	Squid	7	2617	30910
	Butter	3	108738	19436
	Finfish	1	370	17
	Mix flounder	1	0	1
	Mix groundfish	5	7404	15417
	Silver hake	17	1289	6770

Table B3. Continued; 1994-1998

Year	Target	Trips	Landings	Discard
1994	None	2	250	336
	Scup	2	515	3407
	Fluke	14	179	812
	Other	7	2183	10787
	Squid	9	3965	7155
	Butter	2	94957	1682
	Finfish	1	7	7
	Mix groundfish	5	4115	3773
	Silver hake	2	27	178
1995	Scup	1	330	365
	Fluke	21	192	3280
	Other	10	10965	14730
	Squid	7	127	3734
	Mix groundfish	3	52	22
	Silver hake	21	1581	324
1996	Fluke	11	1443	3172
	Other	25	37852	4331
	Squid	9	3041	21874
	Butter	1	2351	1591
	Mix groundfish	1	0	1
	Silver hake	26	74	73
1997	Scup	2	20	210
	Fluke	5	2385	1597
	Other	13	14040	34947
	Squid	24	7755	6781
	Butter	5	33088	9691
	Finfish	2	0	71
	Mix flounder	1	2	4
	Mix groundfish	1	0	1
	Silver hake	4	554	68
1998	None	3	1026	1694
	Fluke	5	1245	1619
	Other	6	1433	15381
	Squid	14	6273	5301
	Mix flounder	1	0	1
	Silver hake	4	781	2821

Table B3. Continued; 1999-2003

Year	Target	Trips	Landings	Discard
1999	None	3	91	42
	Scup	1	200	118
	Fluke	1	398	7050
	Other	10	18133	59380
	Squid	33	3296	121022
	Butter	1	3850	2050
	Mix groundfish	1	0	1
	Silver hake	11	61	131
2000	Scup	3	25	59
	Fluke	4	0	12
	Other	22	38237	120912
	Squid	26	5310	46843
	Mix flounder	1	0	13
	Mix groundfish	4	36	20
	Silver hake	6	280	18
2001	Scup	4	205	135
	Fluke	7	5	59
	Other	14	245	7360
	Squid	40	15508	80234
	Butter	1	0	160
	Silver hake	9	2169	3351
2002	Scup	4	15	2
	Fluke	21	115	75
	Other	18	420	745
	Squid	36	6731	23726
	Butter	1	67	96
	Silver hake	10	529	160
2003	Scup	5	126	11
	Fluke	17	115	85
	Other	6	278	7517
	Squid	12	812	5693
	Silver hake	3	123	508

Table B4. Landings, discards, discard ratios, and sample size (N) during 1994-2002 from the NMFS VTR database (for half year intervals and trips 600 lbs or less and greater than 600 lbs) using an aggregate approach (summed discards/ summed landings) with all trips included.

Year	Half	600				>600			
		Landings	Discard	Dratio	N	Landings	Discard	Dratio	N
1994	1	42.0	15.4	.367	756	64.7	100.1	1.547	1028
	2	56.1	8.0	.143	83	281.9	60.4	.214	217
1995	1	32.7	49.4	1.511	580	40.1	43.8	1.092	819
	2	200.0	88.4	.442	155	118.9	50.1	.421	89
1996	1	35.0	69.5	1.985	552	52.3	22.7	.434	1048
	2	930.3	99.6	.107	147	142.0	33.5	.236	165
1997	1	37.2	17.5	.471	556	57.3	21.7	.378	1116
	2	317.2	37.7	.119	154	101.2	11.4	.113	103
1998	1	31.5	22.6	.716	502	36.1	17.4	.481	853
	2	313.6	41.6	.132	127	43.1	5.5	.127	54
1999	1	33.2	9.7	.293	534	33.1	37.8	1.142	821
	2	133.8	5.1	.038	73	83.2	6.9	.082	101
2000	1	30.2	20.0	.663	607	39.0	13.8	.354	855
	2	26.6	4.9	.185	43	111.5	19.0	.170	87
2001	1	34.0	10.2	.301	528	36.3	13.5	.371	757
	2	1464.1	39.4	.027	162	69.4	8.7	.126	119
2002	1	24.3	22.7	.932	491	22.4	30.8	1.374	597
	2	119.3	5.3	.044	62	26.2	2.2	.085	38

Table B5. Landings, discards, discard ratios, and sample size (N) during 1989-2002 from observed tows in the NMFS observer program (for half year intervals and trips 600 lbs or less and greater than 600 lbs) using an aggregate approach (summed discards/ summed landings) with all trips included.

Year	Half	600				>600			
		Land	Discard	Dratio	N	Land	Discard	Dratio	N
1989	1	1642	5066	3.08526	26	15621	962	0.06158	3
	2	1584	8254	5.21086	39	20257	34192	1.68791	12
1990	1	808	3337	4.12995	22	13262	4419	0.33321	9
	2	1514	4178	2.75958	31	3058	1978	0.64683	3
1991	1	3332	23654	7.12041	45	43992	2183	0.04962	3
	2	4650	41101	8.83892	70	52583	59313	1.12799	9
1992	1	1816	10539	5.8034	52	14213	36990	2.6025	7
	2	2365	19342	8.1784	36	3936	42307	10.7487	4
1993	1	1996	6304	3.1583	22	13986	16496	1.1795	3
	2	1718	21208	12.3446	20	106723	51958	0.4868	5
1994	1	56	11.5	0.2054	4	na	na	na	Na
	2	1594	7055	4.4268	17	4426	13837	3.1263	2
1995	1	3336	11263	33.5012	42	10668	12005	1.1253	1
	2	3532	6281	1.7785	91	na	na	na	Na
1996	1	2526	11939	4.7257	37	4494	16041	3.56982	3
	2	3343	5203	1.55647	92	41216	7934	0.19251	8
1997	1	1458	3109	2.13317	37	51919	45294	0.87241	11
	2	1188	3265	2.7484	17	3599	1759	0.48875	2
1998	1	2363	4081	1.72704	18	6584	18465	2.80453	5
	2	1311	3336	2.54424	21	2292	1510	0.65881	2
1999	1	3231	33517	10.372	27	8151	17152	2.104	4
	2	780	132355	169.687	34	13870	6790	0.490	2
2000	1	1400	39346	28.105	33	4684	8458	1.806	3
	2	386	85939	222.639	31	37460	34175	0.912	2
2001	1	1530	44277	28.9392	38	16117	32360	2.0078	6
	2	632	15075	23.853	34	na	na	na	Na
2002	1	153	1301	8.5318	29	6318	10625	1.6817	1
	2	1609	13005	8.08272	65	1460	1651	1.13082	1

Table B6. Discard ratios , and sample size (N) during 1989-2002 from observed tows in the NMFS observer program (for half year intervals and trips 600 lbs or less and greater than 600 lbs) using a geometric mean discard ratio (retransformed, mean D/L by trip) for matched trips with landings and discards only.

Year	Half	600	N	>600	N
1989	1	2.531255	17	0.989597	3
	2	4.347187	20	1.593124	12
1990	1	2.681034	12	1.240319	8
	2	3.62086	15	1.478619	3
1991	1	3.795113	32	1.231818	3
	2	4.607233	42	1.806282	9
1992	1	3.142323	15	2.025193	7
	2	2.29842	15	2.49667	4
1993	1	2.793747	16	1.441397	3
	2	3.222019	13	2.011631	5
1994	1	0.471726	3	na	na
	2	2.702608	9	2.082737	2
1995	1	39.94192	18	1.753105	1
	2	2.793871	32	na	Na
1996	1	2.51086	18	2.208343	3
	2	3.403395	29	1.204729	7
1997	1	1.814747	16	1.504132	11
	2	2.220992	7	1.404974	2
1998	1	1.938916	12	1.723983	5
	2	3.548073	8	1.181671	2
1999	1	3.048545	16	2.090695	3
	2	3.636889	10	1.512366	2
2000	1	3.036537	14	1.926607	3
	2	1.660259	7	1.807028	2
2001	1	2.132316	19	1.734414	6
	2	1.418301	5	na	na
2002	1	4.240989	9	1.884612	1
	2	2.924087	13	1.764504	1

Table B7. Discard ratios (retransformed), otter trawl landings (tonnes), discard by otter trawls (tonnes) for half year and landings category (<600, >600), and total otter trawl discards (tonnes) during 1989-2002.

Year	Half	Dratio		Landings		Discard		Total Discard
		600	>600	600	>600	600	>600	
1989	1	2.531	0.989	63.9	1097.9	161.7	1086.5	4441.9
	2	4.347	1.593	97.0	1740.0	421.7	2772.0	
1990	1	2.681	1.240	86.8	978.4	232.7	1213.5	3019.7
	2	3.621	1.479	98.6	822.7	357.0	1216.5	
1991	1	3.795	1.232	72.6	1092.3	275.5	1345.5	3451.5
	2	4.607	1.806	87.3	790.7	402.2	1428.2	
1992	1	3.142	2.025	70.2	1692.2	220.6	3427.0	5697.9
	2	2.298	2.497	93.3	735.3	214.4	1835.8	
1993	1	2.794	1.441	83.0	824.1	231.9	1187.9	8477.8
	2	3.222	2.012	95.1	3356.3	306.4	6751.6	
1994	1	0.472	0.472	102.6	2082.2	48.4	982.2	3700.7
	2	2.703	2.083	107.2	1142.9	289.7	2380.4	
1995	1	39.942	1.753	119.8	1065.0	4785.0	1867.1	8599.1
	2	2.794	2.794	182.2	514.7	509.0	1438.0	
1996	1	2.511	2.208	167.2	2222.7	419.8	4908.5	6822.8
	2	3.403	1.205	198.0	681.2	673.9	820.7	
1997	1	1.815	1.504	172.5	1435.2	313.0	2158.7	3852.2
	2	2.221	1.405	227.1	623.5	504.4	876.0	
1998	1	1.939	1.724	179.6	1140.9	348.2	1966.9	3274.4
	2	3.548	1.182	176.5	281.8	626.2	333.0	
1999	1	3.049	2.091	190.1	1023.2	579.5	2139.2	4115.4
	2	3.637	1.512	154.2	552.7	560.8	835.9	
2000	1	3.037	1.927	131.6	227.3	399.6	437.9	2427.0
	2	1.660	1.807	151.5	740.4	251.5	1337.9	
2001	1	2.132	1.734	156.1	3562.8	332.9	6179.4	7261.7
	2	1.418	1.418	147.6	380.8	209.3	540.1	
2002	1	4.240	1.885	123.8	371.3	525.0	699.8	1809.2
	2	2.924	1.765	114.6	141.3	335.1	249.3	

Table B8. NEFSC indices in number and weight per tow (kg) for the Spring 1968-2002, Winter 1992-2002, and Autumn 1968-2002.

	Spring		Winter		Fall	
Year	# Spr	wt Spr	#Win	wt Win	#Fall	wt Fall
1968	33.139	1.956			90.838	7.86
1969	30.771	3.082			55.986	3.936
1970	9.871	0.515			35.235	2.282
1971	21.721	0.762			180.352	4.313
1972	228.075	6.643			68.976	2.767
1973	68.697	5.354			128.94	6.161
1974	25.258	1.72			86.845	4.06
1975	121.071	3.997			41.939	2.56
1976	31.148	1.308			122.304	5.671
1977	7.013	0.559			78.6	5.088
1978	4.654	0.25			78.272	3.614
1979	12.855	1.047			312.721	12.703
1980	58.182	3.197			313.711	15.06
1981	43.805	2.474			249.5	9.259
1982	49.188	2.549			88.393	4.134
1983	64.743	3.897			398.308	12.454
1984	15.837	0.711			332.506	11.243
1985	37.842	1.601			402.648	15.77
1986	66.206	2.784			162.941	5.967
1987	15.619	0.574			119.979	5.106
1988	13.353	0.478			268.748	7.277
1989	32.311	0.761			383.507	11.783
1990	8.928	0.36			406.732	9.899
1991	27.836	1.009			127.086	4.045
1992	17.949	0.607	20.099	0.769	263.224	4.917
1993	26.684	0.807	117.86	2.623	269.281	10.821
1994	36.294	1.45	169.513	6.255	542.882	13.81
1995	42.105	2.205	139.746	3.516	114.738	5.843
1996	11.47	0.512	67.663	1.351	72.479	2.867
1997	112.867	3.414	38.056	1.8	123.46	2.756
1998	41.07	2.144	40.123	0.975	231.036	7.097
1999	76.227	2.457	42.732	1.433	257.115	4.93
2000	36.773	0.99	153.673	5.07	181.611	7.515
2001	61.21	1.888	69.338	3.403	59.671	2.541
2002	46.572	1.705	44.859	1.925	36.411	1.29
2003	47.697	1.394				

Table B9. Catch per tow in number for NEFSC Spring surveys during 1982-2002 for ages 1-4.

Year	1	2	3	4
1982	36.0963	10.3065	2.3095	0.376
1983	33.815	22.9983	7.0392	0.8807
1984	10.8769	3.9009	0.9936	0.0658
1985	30.1886	4.9152	2.2178	0.464
1986	53.0479	12.0466	1.0129	0.0986
1987	13.9306	1.4298	0.2285	0.0228
1988	11.2921	1.8751	0.175	0.0113
1989	25.6435	5.7061	0.955	0.0059
1990	7.2205	1.3561	0.322	0.0297
1991	25.6657	1.4995	0.6257	0.0189
1992	16.0983	1.6132	0.2277	0.0098
1993	23.5588	2.7051	0.4205	0
1994	29.5594	5.6517	1.0395	0.0439
1995	26.5474	12.9457	2.6121	0
1996	7.7336	2.4142	1.2748	0.0477
1997	107.6083	4.6109	0.6476	0
1998	18.3203	21.5421	1.2072	0
1999	64.9677	9.2975	1.9621	0
2000	34.7082	1.6964	0.3287	0.0399
2001	49.2793	11.1395	0.7916	0
2002	38.1848	6.0295	2.1145	0.2429

Table B10. Catch per tow in number for NEFSC Autumn surveys during 1982-2002 for ages 0-3.

1982	57.752	24.9283	5.449	0.263
1983	303.883	82.9381	12.5132	1.4906
1984	282.965	39.0889	9.4107	1.0415
1985	319.562	74.7958	7.0782	1.1762
1986	126.467	24.8369	10.718	0.7787
1987	80.054	32.4701	7.1747	0.2803
1988	227.351	26.9924	14.2919	0.1126
1989	329.203	43.8711	10.2556	0.1772
1990	374.130	28.7001	3.4882	0.4142
1991	107.044	17.7069	2.0452	0.0194
1992	248.296	11.1541	3.7618	0.0117
1993	214.428	49.0602	5.4212	0.365
1994	504.598	26.917	10.6311	0.7043
1995	28.798	55.9273	29.9941	0.0189
1996	55.105	12.653	4.522	0.1984
1997	106.028	15.1555	2.0254	0.2516
1998	184.755	39.9448	5.3688	0.9673
1999	252.689	2.944	1.4821	0
2000	120.217	54.662	6.4658	0.2662
2001	29.317	18.3819	11.7222	0.2503
2002	28.921	4.6756	2.7507	0.0638

Table B11. Catch per tow in weight (kg) at age for NEFSC Autumn survey during 1982-2002 and for age 0 and 1+ during 1968-2002.

Year	0	1	2	3	0	1+
1968					0.2721	7.5879
1969					0.5397	3.3963
1970					0.8697	1.4123
1971					3.5352	0.7778
1972					2.2240	0.5430
1973					2.1216	4.0394
1974					1.9627	2.0973
1975					0.4952	2.0648
1976					1.9865	3.6845
1977					0.6372	4.4508
1978					2.4720	1.1420
1979					8.4353	4.2677
1980					4.5015	10.5585
1981					5.4677	3.7913
1982	1.5889	1.9977	0.5113	0.0364	1.5889	2.5454
1983	6.0358	5.1317	1.1389	0.1413	6.0358	6.4119
1984	7.3119	2.9419	0.8813	0.1083	7.3119	3.9315
1985	9.9567	4.9959	0.6987	0.1106	9.9567	5.8135
1986	3.1965	1.6832	0.9635	0.1093	3.1965	2.7702
1987	2.4951	2.056	0.5186	0.0362	2.4951	2.6108
1988	4.8221	1.4363	1.0035	0.0156	4.8221	2.4554
1989	8.3915	2.5959	0.7731	0.0222	8.3915	3.3912
1990	7.8038	1.7182	0.3318	0.0453	7.8038	2.0953
1991	2.6807	1.205	0.1565	0.0025	2.6807	1.3640
1992	3.9053	0.7087	0.3017	0.0019	3.9053	1.0123
1993	7.0499	3.2878	0.4401	0.0433	7.0499	3.7712
1994	11.0023	1.7917	0.9472	0.0647	11.0023	2.8080
1995	0.6757	3.3177	1.8463	0.003	0.6757	5.1670
1996	1.8175	0.6851	0.3494	0.0155	1.8175	1.0500
1997	1.5989	0.9855	0.1527	0.0185	1.5989	1.1567
1998	3.7522	2.7767	0.4712	0.0971	3.7522	3.3450
1999	4.676	0.1557	0.0978		4.6760	0.2535
2000	2.8136	4.1282	0.542	0.0311	2.8136	4.7013
2001	0.8906	0.9876	0.6409	0.0233	0.8906	1.6518
2002	0.8257	0.2412	0.2149	0.0082	0.8257	0.4643

Table B12. Indices in weight-per-tow for Rhode Island (1981-2002), Massachusetts (1982-2002), Connecticut (1984-2002) and the Virginia Institute of Marine Science (1988-2001).

Year	RI	MA	CT	VIMS
1981	1.200			
1982	1.200	2.790		
1983	1.200	2.787		
1984	3.000	1.787	8.639	
1985	1.100	1.433	16.770	
1986	4.200	4.414	10.978	
1987	2.500	0.688	7.856	
1988	12.300	11.684	15.412	0.008
1989	2.900	2.523	17.760	0.037
1990	5.500	2.552	13.318	0.025
1991	2.000	3.174	15.011	0.029
1992	3.500	8.874	22.623	0.010
1993	5.300	10.306	22.304	0.026
1994	5.600	7.286	11.130	0.008
1995	4.600	5.328	41.030	0.004
1996	2.800	6.605	23.016	0.025
1997	9.300	7.904	16.559	0.005
1998	4.600	14.479	51.376	0.015
1999	3.300	7.788	44.908	0.009
2000	0.880	3.175	27.605	0.016
2001	2.200	1.771	22.128	0.019
2002	2.000	3.844	26.520	na

Table B13 Estimates of instantaneous total mortality rates from spring survey catch per tow (number) at age (age 1-3) during 1982-2002.

Year	Age-1	Age-2	Age-3
1982-1983	0.451	0.381	.0964
1983-1984	2.160	3.142	4.673
1984-1985	0.794	0.565	0.761
1985-1986	0.919	1.580	3.113
1986-1987	3.614	3.965	3.794
1987-1988	2.005	2.101	3.007
1988-1989	0.683	0.675	3.390
1989-1990	2.940	2.875	3.471
1991-1992	1.572	0.773	2.835
1992-1993	2.767	1.885	4.156
1993-1994	1.784	1.345	Na
1994-1995	1.428	0.956	2.260
1995-1996	0.826	0.772	Na
1996-1997	2.398	2.318	4.003
1997-1998	0.517	1.316	Na
1998-1999	1.608	1.340	Na
1999-2000	0.678	2.396	Na
2000-2001	3.645	3.342	3.895
2001-2002	1.136	0.762	Na
	2.101	1.662	1.181
Average 1982-2001	1.701	1.707	2.965

Table B14. Estimates of instantaneous total mortality rates from autumn surveys catch per tow (number) at age (age 0-2) during 1982-2002.

Year	Age-0	Age-1	Age-2
1982-1983	-0.362	0.689	1.296
1983-1984	2.051	2.176	2.486
1984-1985	1.331	1.709	2.080
1985-1986	2.555	1.943	2.207
1986-1987	1.360	1.242	3.644
1987-1988	1.087	0.821	4.154
1988-1989	1.645	0.968	4.390
1989-1990	2.440	2.532	3.209
1990-1991	3.051	2.641	5.192
1991-1992	2.261	1.549	5.164
1992-1993	1.622	0.721	2.333
1993-1994	2.075	1.529	2.041
1994-1995	2.200	-0.108	6.332
1995-1996	0.822	2.515	5.018
1996-1997	1.291	1.832	2.889
1997-1998	0.976	1.038	0.739
1998-1999	4.139	3.294	Na
1999-2000	1.531	-0.787	1.717
2000-2001	1.878	1.540	3.252
2001-2002	1.836	1.900	5.213
Average 1982-2001	1.789	1.487	3.335

Table B15. Table of Lamdas used in profile and model runs to decide on final FPA model for butterfish.

	Profile over M	Profile over S	Estimate Catch	NO Constraints
NEFSC Surveys	1	1	1	1
Catch Deviations	10000	10000	1	10000
Natural Mortality	10000	0	0	0
Survey Survival Rates	0	10000	0	0
Minimum Swept Area Biomass	0	0	0	0
Constraint on C/B *	10000	10000	10000	10000
Constraint on IGR **	10000	10000	10000	10000
Fox Surplus Production	0.0001	0.0001	0.0001	0.0001

* Catch/ Biomass
** Initial Growth Rate

Table B16. Profile table for values of natural mortality (M) from 0.6-1.4

	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	
OBJ Function Major components									
Surveys-All	157.2683	155.2894	154.4288	153.4335	152.645977	152.1255	151.7644	151.5903	151.4414
Fit to recruitment model	4.338488	3.730925	2.417835	1.355338	0.380699673	-0.55549	-1.47755	-2.43697	-3.3003
Estimate some catches	2065.235	2065.235	2065.235	2065.235	2065.235267	2065.235	2065.235	2065.235	2065.235
Prior Q min swept biomass	0	0	0	0	0	0	0	0	0
Prior on log(variance recruit residuals)	0	0	0	0	0	0	0	0	0
Prior Q on Survey Z's	0	0	0	0	0	0	0	0	0
--Not used--	0	0	0	0	0	0	0	0	0
--Not used--	0	0	0	0	0	0	0	0	0
--Not used--	0	0	0	0	0	0	0	0	0
Constrain initial IGR values	2.861435	2.898323	2.416549	2.115867	1.81203703	1.535867	1.297357	1.07773	0.879218
--Not used--	0	0	0	0	0	0	0	0	0
Constrain B-zero	3.57E-05	4.04E-07	5.37E-09	2.15E-05	1.51284E-07	3.82E-06	2.28E-06	2.07E-10	5.22E-07
--Not used--	0	0	0	0	0	0	0	0	0
--Not used--	0	0	0	0	0	0	0	0	0
--Not used--	0	0	0	0	0	0	0	0	0
Pella and Tomlinson Production Model	0	0	0	0	0	0	0	0	0
Shaeffer Production Model	0.002271	0.004296	0.006613	0.009453	0.01315071	0.017264	0.021574	0.02537	0.029099
--Not used--	0	0	0	0	0	0	0	0	0
Max C/B	0	0	0	0	0	0	0	0	0
--Not used--	0	0	0	0	0	0	0	0	0
Total Log Likelihood (weighted sum)	164.4718	161.9187	159.2632	156.9069	154.838742	153.1063	151.5844	150.231	149.0204
Schaefer model parameters									
External or internal?	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal	Internal
Alpha	0.627703	0.591564	0.618506	0.627018	0.628474389	0.63078	0.631489	0.629397	0.629407
Beta	-8.84157	-7.54804	-7.35774	-6.80587	-6.22094039	-5.7597	-5.35834	-5.04647	-4.83736
Log Likelihood	0.002271	0.004296	0.006613	0.009453	0.01315071	0.017264	0.021574	0.02537	0.029099
RMS Residuals	0.011232	0.015448	0.019167	0.022917	0.027029521	0.030969	0.03462	0.037543	0.040207
Carrying Capacity (K)	0.070994	0.078373	0.084062	0.092129	0.101025625	0.109516	0.117852	0.12472	0.130114
Bmsy (units=1000)	0.035497	0.039187	0.042031	0.046065	0.050512812	0.054758	0.058926	0.06236	0.065057
MSY (units=1000)	0.011141	0.011591	0.012998	0.014442	0.015873004	0.01727	0.018606	0.019625	0.020474
Fmsy	0.313851	0.295782	0.309253	0.313509	0.314237194	0.31539	0.315744	0.314699	0.314703
Recent Mean F / Fmsy	1.393003	0.883073	0.673704	0.58118	0.520863075	0.484367	0.462432	0.455616	0.452324
Recent Mean B / Bmsy	23.40385	38.21355	49.58598	59.36334	69.35057221	78.09034	85.77665	91.52304	96.51873
Recent Mean C/ MSY	0.659315	0.97517	1.179747	1.288699	1.372930333	1.426098	1.455671	1.467652	1.483606

Table B17. Values for profile of q on survey survival rates (S) for q=.2-1.0.

	q=.2	q=.3	q=.4	q=.5	q=.6	q=.7	q=.8	q=.9	q=1.0
Survey_trends	155.07	155.028	150.843	152.475	154.966	157.494	159.925	162.274	164.548
Fox_surplus_production	287.7	284.828	-56.5606	-76.7152	-82.3336	-84.832	-87.0526	-89.4808	-91.4909
Catch	1.7224E-12	1.6371E-12	2.46252E-08	1.25464E-07	2.22628E-07	2.9364E-07	3.46571E-07	3.91211E-07	4.31633E-07
Trend_Winter.Survey.Age.1+	7.21195	7.21216	6.72445	6.3539	6.41156	6.53163	6.69042	6.89332	7.12136
Trend_Spring.Survey.Age.1+	62.5476	62.528	57.3501	55.1018	54.2918	54.1205	54.1257	54.1949	54.3097
Trend_Fall.Survey.Age.0	20.8195	20.8042	27.2192	35.4202	40.375	43.6616	46.1282	48.1598	49.9286
Trend_Fall.Survey.Age.1+	64.4899	64.4823	59.5485	55.5977	53.8863	53.1789	52.9795	53.0243	53.1873
Trend_Fall.Survey.Min.Biomass.0+	43.5104	43.5036	51.8364	59.4435	64.918	68.9716	72.2249	74.9924	77.3955
Trend_Murawski.and.Waring.1979	15.6572	15.6484	28.5482	35.0743	37.7288	39.307	40.3508	41.0771	41.5941
Trend_Fall.survey.RI.1+	239.301	240.134	236.282	288.535	326.214	357.559	385.793	411.427	434.427
Trend_Fall.Survey.MA.1+	281.521	282.132	281.287	317.833	343.918	365.473	385.032	403.037	419.401
Trend_Fall.Survey.CT.1+	141.598	141.91	145.325	169.407	186.547	200.342	212.293	222.88	232.264
Trend_Fall.survey.VIMS.age.0	196.815	196.842	189.725	177.992	167.992	160.834	156.649	154.271	152.861
Trend_Survey.Survival.Ratio	21.6794	21.6794	22.62	24.3249	25.6297	26.668	27.5499	28.3375	29.0614
Total_LogLikelihood	3554.78	437.043	159.233	159.498	161.26	163.286	165.344	167.4	169.433
Target	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Residual	0.150941	0.0509412	0.000183598	-0.00014306	-0.00026006	-0.00033764	-0.00040197	-0.00045819	-0.00050401
Weight	10000	10000	10000	10000	10000	10000	10000	10000	10000
Q_for_adj_biomass	0.00014424	0.000141783	1.81411	5.23293	8.42295	11.4491	14.3475	17.1416	19.8508
Q_for_adj_biomass	0.350941	0.350941	0.400184	0.499857	0.59974	0.699662	0.799598	0.899542	0.999496
Bmsy=	8.17936E+25	421.368	0.046822	0.0288417	0.0250699	0.0232438	0.0222597	0.0216458	0.0211955
MSY=	9.89103E-34	150.466	0.0238747	0.0149227	0.0133047	0.0125389	0.0120472	0.0118163	0.0116405
Fmsy=	1.20927E-59	0.35709	0.509903	0.517399	0.530705	0.539452	0.541213	0.545892	0.549195
Recent_F/Fmsy=	7.21418E+53	2.60087E-05	0.239964	0.687924	1.04468	1.33497	1.59235	1.80553	1.99476
Recent_B/Bmsy=	1.14387E-23	2.25819	1.66893	1.06632	0.857803	0.748092	0.675702	0.625452	0.589705
AveBiomass	400413	407198	28.5609	8.5467	4.97495	3.58286	2.85392	2.40857	2.11068
av biomass last 3 yrs	703668.6667	715637	56.35876667	20.6328	13.59465	10.42220333	8.59135	7.40651	6.57822
av F last 3 yrs	9.44528E-06	9.28746E-06	0.122358733	0.355931333	0.554416667	0.720154	0.861802333	0.985623667	1.095515667

Table B18. Profile table of sensitivity of model results to changes in the CV (0.1-0.5) of catch (catches estimated with error) for the FPA model.

	catch cov on cv=0.1	catch cov on cv=0.2	catch cov on cv=0.3	catch cov on cv=0.4	catch cov on cv=0.5
Time	10/27/03 9:39	10/27/03 9:38	10/27/03 9:36	10/27/03 9:35	10/27/03 9:34
Survey_trends	150.768	148.617	138.098	129.411	123.695
Fox_surplus_production	-69.6275	-79.8233	-93.8058	-94.0182	-92.62
Catch	0.259454	2.16052	9.97362	11.8942	12.0244
Trend_Winter.Survey.Age.1+	6.43476	6.0129	5.57008	5.11559	4.82419
Trend_Spring.Survey.Age.1+	56.1161	54.9585	54.4983	54.8833	55.0064
Trend_Fall.Survey.Age.0	30.9963	33.9404	32.6911	28.2863	25.309
Trend_Fall.Survey.Age.1+	57.2196	53.7041	45.337	41.1251	38.5546
Trend_Fall.Survey.Min.Biomass.0+	55.4735	60.3136	67.2707	67.3579	67.0014
Trend_Murawski.and.Waring.1979	32.2986	35.019	35.9879	34.4148	33.2191
Trend_Fall.survey.RI.1+	259.516	279.896	291.11	314.179	317.262
Trend_Fall.Survey.MA.1+	297.593	311.755	324.056	341.34	342.446
Trend_Fall.Survey.CT.1+	156.275	167.007	180.568	187.51	187.508
Trend_Fall.survey.VIMS.age.0	184.218	174.745	155.835	149.603	145.231
Trend_Survey.Survival.Ratio	23.2842	23.3919	21.0917	17.8768	15.8297
Total_LogLikelihood	158.658	157.52	153.231	146.708	141.352
Q_Scaled_For_Calcs	NA	NA	NA	NA	NA
Target	NA	NA	NA	NA	NA
GOF	NA	NA	NA	NA	NA
Q_for_adj_biomass	3.31625	5.79431	12.3871	14.3822	14.4204
Q_for_adj_biomass	0.442758	0.514011	0.691449	0.702151	0.664409
Bmsy=	0.0340772	0.0272124	0.0227296	0.0228949	0.024381
MSY=	0.0175955	0.0137463	0.00991316	0.00975001	0.00968692
Fmsy=	0.516342	0.505148	0.436134	0.425859	0.397315
Recent_F/Fmsy=	0.437924	0.755526	1.53507	1.6421	1.72614
Recent_B/Bmsy=	1.32094	1.02484	0.633107	0.53394	0.49644
AveBiomass	14.491	7.68074	3.48882	3.13679	3.21028
av biomass last 3 yrs	31.41143333	18.60518	8.921896667	7.585903333	7.599196667
av F last 3 yrs	0.226118367	0.381652	0.669496	0.699302	0.68582

Table B19. Values for Goodness of Fit values for final set of model runs and final model chosen by the Working Group.

Final Run

covariates on
covariates on
covariates on
covariates on

Son=.4 No Cv on catch
noS noCV on catch
Son=.6 No CV on catch
noS Cv on catch=.1

Time

11/13/03 14:10
11/13/03 14:02
11/13/03 14:16
11/13/03 14:23

Survey_trends

152.949
153.043
155.516
152.488

Fox_surplus_production

-63.9732
-80.0318
-91.3943
-83.2247

Catch

1.11635E-11
3.52805E-11
9.45914E-11
0.443018

Trend_Winter.Survey.Age.1+

7.00817
6.60443
6.48451
6.45534

Trend_Spring.Survey.Age.1+

58.0204
56.2417
54.3275
55.7888

Trend_Fall.Survey.Age.0

27.3662
32.6738
40.5746
33.8033

Trend_Fall.Survey.Age.1+

60.5531
57.5225

54.1283
56.4399

Trend_Fall.Survey.Min.Biomass.0+

63.5605
77.547
106.233
81.8751

Trend_Murawski.and.Waring.1979

51.6593
57.4801
62.8181
58.5762

Trend_Fall.survey.RI.1+

228.49
259.753
312.097
266.092

Trend_Fall.Survey.MA.1+

274.961
296.725
332.926
300.989

Trend_Fall.Survey.CT.1+

141.38
155.989
180.549
159.254

Trend_Fall.survey.VIMS.age.0

191.81
184.591
170.106
181.776

Trend_Survey.Survival.Ratio

22.6327
23.723
25.729
23.8611

Total_LogLikelihood

162.351
161.513
162.838
161.118

Q_Scaled_For_Calcs

0.4

NA

0.6

NA

Target

0.000285961

NA

-0.000193041

NA

GOF

10000

NA

10000

NA

Q_for_adj_biomass

0.689267
1.29052
2.41649
1.49401

Q for Survival S

0.400286
0.458972
0.599807
0.480088

Bmsy=

0.0442258
0.0315659
0.0265243
0.0299606

MSY=

0.0193932
0.0137439
0.0114972
0.0128212

Fmsy*0.71=

0.438503
0.435403
0.433458
0.427937

Recent_F/Fmsy=

0.267727
0.583193
1.24839
0.70419

Recent_B/Bmsy=

1.73588
1.21776
0.779495
1.10563

av biomass last 3 yrs

57.32266667
27.5442
13.68610667
23.4252

Av F last 3 yrs

0.1173994
0.2539237
0.541126667
0.301348833

Table B20. Table of emphasis coefficients used in the final model for butterfish.

Likelihood Term	Emphasis Coefficient
NEFSC Surveys	1
Catch	10000
Constraint C/B	10000
Constraint IGR	10000
Fox Surplus Production	0.0001

Table B21. Parameters estimated in the final model for butterfish.

index	name	point est	STD	CV
1	log_escapement_fyear	3.21	1.0959	0.341402
2	log_total_biom_prior_fyear	3.8105	0.94801	0.248789
3	log_mean_recr	2.9126	0.16296	0.05595
4	recruit_devs	0.059098	0.88869	15.03756
5	recruit_devs	1.3582	0.3287	0.242011
6	recruit_devs	-1.4008	0.74111	-0.52906
7	recruit_devs	-0.45544	0.24054	-0.52815
8	recruit_devs	-0.063293	0.19722	-3.11598
9	recruit_devs	0.48946	0.18373	0.375373
10	recruit_devs	0.99078	0.22346	0.225539
11	recruit_devs	0.69755	0.25023	0.358727
12	recruit_devs	0.95444	0.13958	0.146243
13	recruit_devs	-0.030495	0.20942	-6.86736
14	recruit_devs	0.36343	0.1504	0.413835
15	recruit_devs	-1.1016	0.22435	-0.20366
16	recruit_devs	0.48848	0.12249	0.250757
17	recruit_devs	1.1992	0.19574	0.163225
18	recruit_devs	0.27621	0.32175	1.164875
19	recruit_devs	0.81819	0.22257	0.272027
20	recruit_devs	0.38571	0.24297	0.629929
21	recruit_devs	0.75779	0.16815	0.221895
22	recruit_devs	1.0741	0.14009	0.130425
23	recruit_devs	0.37073	0.16984	0.458123
24	recruit_devs	-0.40332	0.18793	-0.46596
25	recruit_devs	-0.25577	0.19725	-0.7712
26	recruit_devs	-0.08615	0.15187	-1.76286
27	recruit_devs	-0.20331	0.1734	-0.85288
28	recruit_devs	-0.11532	0.15347	-1.33082
29	recruit_devs	-1.3695	0.27641	-0.20183
30	recruit_devs	0.28039	0.13957	0.497771
31	recruit_devs	0.48256	0.15242	0.315857
32	recruit_devs	0.52908	0.16039	0.303149
33	recruit_devs	-1.8786	0.27804	-0.148
34	recruit_devs	-0.14247	0.16866	-1.18383
35	recruit_devs	-0.67568	0.18474	-0.27341
36	recruit_devs	-0.65381	0.17138	-0.26213
37	recruit_devs	0.56656	0.24952	0.440412
38	recruit_devs	-0.12354	0.24039	-1.94585
39	recruit_devs	-1.3599	0.36529	-0.26862
40	recruit_devs	-1.8229	0.28466	-0.15616
41	fox_production_log_msy	-4.4084	27.287	-6.18977
42	fox_production_log_bmax	-2.7814	17.194	-6.18178
43	logmeanf	-1.0642	0.32497	-0.30537
44	fdevs	-0.71112	0.83749	-1.17771
45	fdevs	-0.30284	0.97281	-3.21229
46	fdevs	-1.3726	0.15061	-0.10973
47	fdevs	-0.64979	0.14017	-0.21572

Table B21. Cont.

48	fdevs	0.80285	0.11128	0.138606
49	fdevs	0.99409	0.13491	0.135712
50	fdevs	0.28979	0.17815	0.614756
51	fdevs	-0.25261	0.18506	-0.73259
52	fdevs	0.85729	0.1505	0.175553
53	fdevs	0.20487	0.11111	0.542344
54	fdevs	0.46813	0.11939	0.255036
55	fdevs	0.58046	0.12266	0.211315
56	fdevs	0.3421	0.10352	0.302602
57	fdevs	0.11903	0.11511	0.967067
58	fdevs	-1.1009	0.13277	-0.1206
59	fdevs	-0.28058	0.13335	-0.47527
60	fdevs	-0.41052	0.13732	-0.3345
61	fdevs	0.37596	0.11591	0.308304
62	fdevs	-0.3387	0.12312	-0.36351
63	fdevs	0.43158	0.11401	0.264169
64	fdevs	-0.19048	0.10146	-0.53265
65	fdevs	0.16412	0.1083	0.659883
66	fdevs	0.49783	0.10263	0.206155
67	fdevs	-0.35178	0.11395	-0.32392
68	fdevs	0.028659	0.11251	3.925817
69	fdevs	-0.40229	0.10581	-0.26302
70	fdevs	0.12839	0.11432	0.890412
71	fdevs	0.018151	0.12125	6.680073
72	fdevs	0.14334	0.12374	0.863262
73	fdevs	-0.66283	0.11006	-0.16605
74	fdevs	0.36937	0.12667	0.342935
75	fdevs	0.51154	0.10862	0.212339
76	fdevs	0.37879	0.11638	0.307241
77	fdevs	0.2296	0.1271	0.553571
78	fdevs	-0.56275	0.16484	-0.29292
79	fdevs	-1.0407	0.097159	-0.09336
80	fdevs	0.70227	0.097423	0.138726
81	fdevs	-0.0077181	0.17762	-23.0134
82	survey_covariate_pars[1]	0.13958	0.15552	1.1142
83	survey_covariate_pars[4]	-1.0566	0.1188	-0.11244
84	f	0.16944	0.17188	1.0144
85	f	0.25487	0.29001	1.137874
86	f	0.087445	0.022912	0.262016
87	f	0.18015	0.047374	0.26297
88	f	0.77004	0.22384	0.290686
89	f	0.93233	0.25208	0.270376
90	f	0.46099	0.1593	0.345561
91	f	0.268	0.086857	0.324093
92	f	0.81313	0.23371	0.28742
93	f	0.42346	0.11596	0.273839
94	F	0.551	0.16589	0.301071
95	F	0.61649	0.15816	0.256549

Table B21. Continued

96	F	0.48575	0.16343	0.336449
97	F	0.38863	0.12221	0.314464
98	F	0.11474	0.038463	0.335219
99	F	0.26061	0.095212	0.365343
100	F	0.22885	0.082895	0.362224
101	F	0.50248	0.16912	0.336571
102	F	0.24589	0.082366	0.334971
103	F	0.53122	0.16616	0.312789
104	F	0.28518	0.096322	0.337759
105	F	0.40655	0.14778	0.363498
106	F	0.56761	0.18944	0.33375
107	F	0.2427	0.078441	0.323201
108	F	0.35505	0.1196	0.336854
109	F	0.23074	0.075035	0.325193
110	F	0.39229	0.14596	0.372072
111	F	0.35134	0.1148	0.326749
112	F	0.39819	0.1267	0.31819
113	F	0.17782	0.052209	0.293606
114	F	0.49918	0.18532	0.371249
115	F	0.57544	0.17391	0.302221
116	F	0.5039	0.15614	0.309863
117	F	0.43407	0.1492	0.343723
118	F	0.19654	0.081109	0.412684
119	F	0.12186	0.037325	0.306294
120	F	0.69636	0.23541	0.338058
121	F	0.34236	0.15302	0.446956
122	average_biom	33.962	34.451	1.014398
123	average_biom	32.062	36.483	1.137889
124	average_biom	77.183	20.223	0.262014
125	average_biom	48.744	12.818	0.262966
126	average_biom	25.651	7.4563	0.290683
127	average_biom	16.578	4.4824	0.270382
128	average_biom	26.499	9.1566	0.345545
129	average_biom	50.844	16.478	0.324089
130	average_biom	43.406	12.476	0.287426
131	average_biom	49.147	13.458	0.273832
132	average_biom	32.319	9.7307	0.301083
133	average_biom	28.833	7.3971	0.25655
134	average_biom	14.879	5.006	0.336447
135	average_biom	27.839	8.7542	0.314458
136	average_biom	65.284	21.885	0.335228
137	average_biom	55.34	20.218	0.365342
138	average_biom	59.481	21.545	0.362217
139	average_biom	45.52	15.321	0.336577
140	average_biom	49.743	16.662	0.334962
141	average_biom	59.387	18.575	0.312779
142	average_biom	45.686	15.431	0.337762
143	average_biom	29.277	10.642	0.363494

Table B21. Continued

144	average_biom	20.57	6.8653	0.333753
145	average_biom	21.527	6.9576	0.323203
146	average_biom	21.532	7.2533	0.336861
147	average_biom	23.033	7.4901	0.32519
148	average_biom	14.277	5.3121	0.372074
149	average_biom	24.051	7.8587	0.326751
150	average_biom	32.853	10.453	0.318175
151	average_biom	41.232	12.106	0.293607
152	average_biom	21.393	7.9424	0.371262
153	average_biom	18.021	5.4461	0.302209
154	average_biom	13.17	4.0807	0.309848
155	average_biom	12.05	4.1418	0.343718
156	average_biom	31.64	13.057	0.412674
157	average_biom	31.585	9.674	0.306285
158	average_biom	16.741	5.6593	0.33805
159	average_biom	7.8169	3.4937	0.446942
160	spawning_biom	24.78	27.157	1.095924
161	spawning_biom	22.613	29.211	1.291779
162	spawning_biom	62.914	16.405	0.260753
163	spawning_biom	33.956	9.6241	0.283429
164	spawning_biom	12.75	5.2643	0.412886
165	spawning_biom	8.0333	3.2638	0.406284
166	spawning_biom	17.686	7.6615	0.433196
167	spawning_biom	37.61	13.942	0.370699
168	spawning_biom	22.649	9.488	0.418915
169	spawning_biom	32.963	10.958	0.332433
170	spawning_biom	19.154	7.4136	0.387052
171	spawning_biom	16.986	5.7037	0.335788
172	spawning_biom	8.9683	3.7709	0.42047
173	spawning_biom	19.248	7.2716	0.377785
174	spawning_biom	52.617	18.673	0.354885
175	spawning_biom	38.586	16.114	0.417613
176	spawning_biom	43.181	17.422	0.403464
177	spawning_biom	27.734	11.694	0.421649
178	spawning_biom	36.19	13.502	0.373086
179	spawning_biom	37.009	14.849	0.401227
180	spawning_biom	31.796	12.154	0.382249
181	spawning_biom	18.417	8.0321	0.436124
182	spawning_biom	12.083	5.1372	0.425159
183	spawning_biom	15.681	5.6008	0.357171
184	spawning_biom	14.566	5.806	0.398599
185	spawning_biom	16.784	6.0351	0.359575
186	spawning_biom	8.9826	4.0245	0.448033
187	spawning_biom	16.859	6.4827	0.384525
188	spawning_biom	22.272	8.5654	0.384582
189	spawning_biom	31.302	9.9205	0.316929
190	spawning_biom	12.357	5.8554	0.473853
191	spawning_biom	10.76	4.1491	0.385604

Table B21. Continued

192	spawning_biom	8.1352	3.1472	0.386862
193	spawning_biom	7.8433	3.3032	0.421149
194	spawning_biom	24.504	11.182	0.456334
195	spawning_biom	24.114	7.589	0.314713
196	spawning_biom	8.6812	4.0326	0.464521

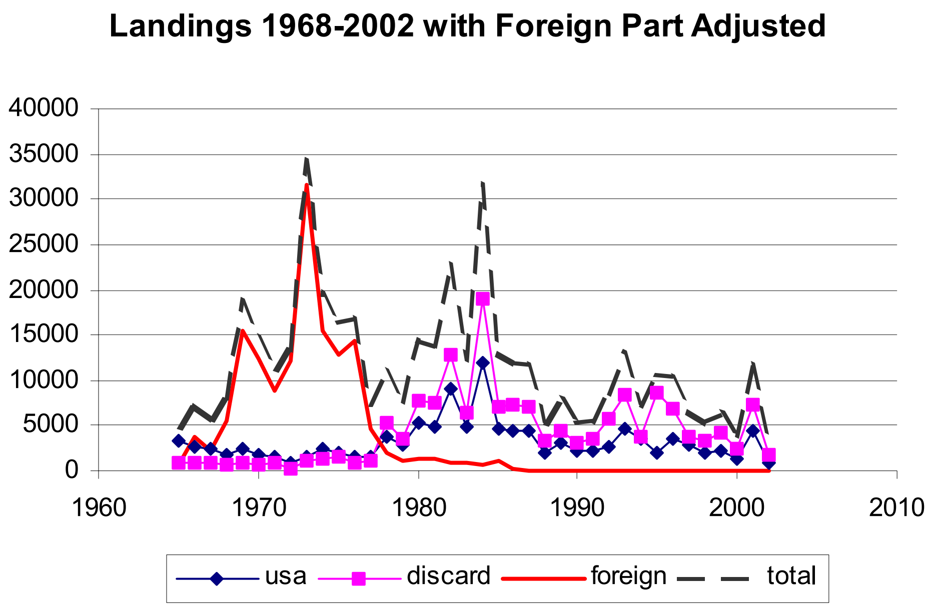


Figure B1. Landings and discards from the USA fishery, foreign landings, and total catch of butterfish during 1965-2002.

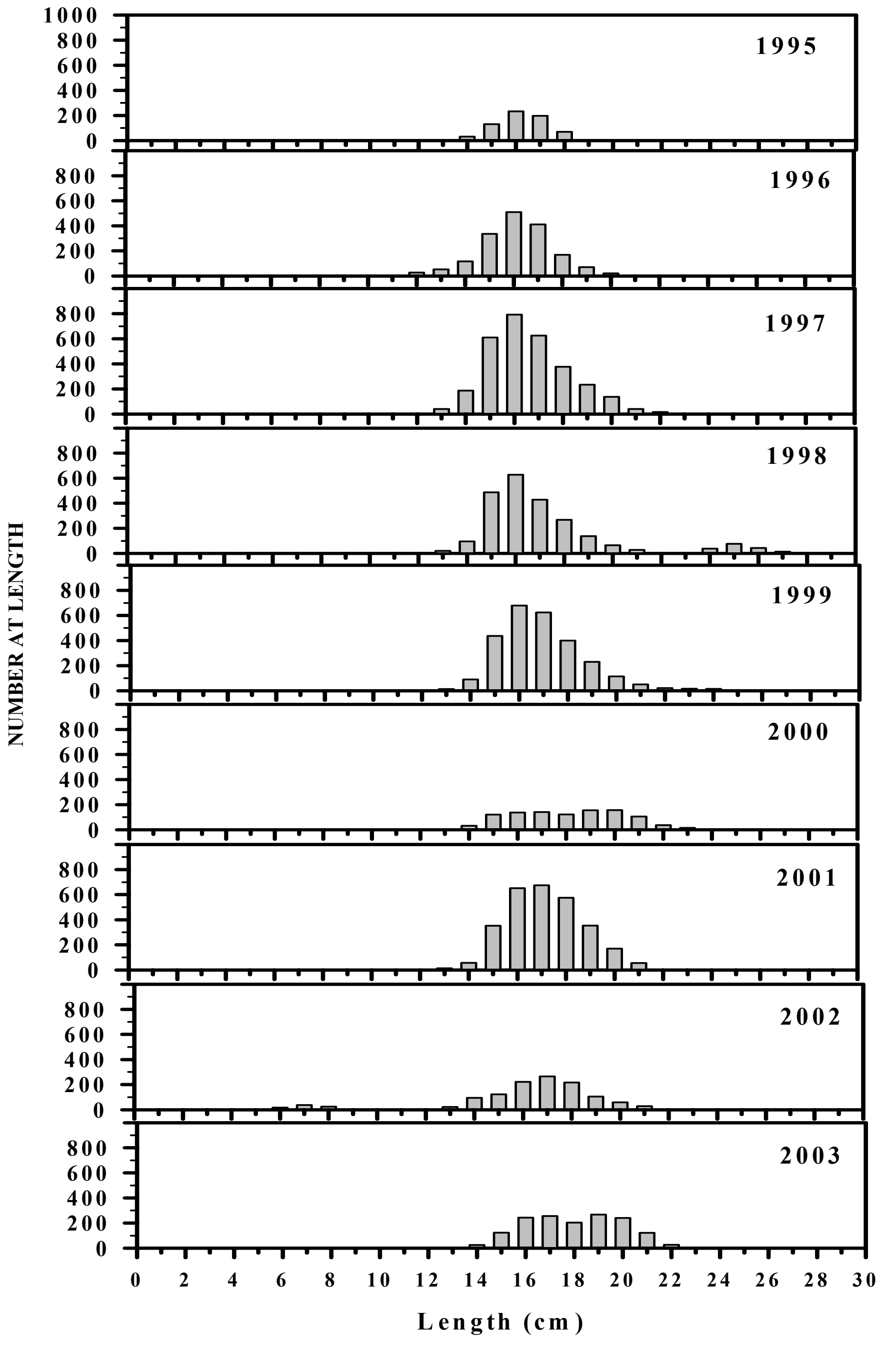


Figure B2. Size composition data from commercial landings of butterfish during 1995-2003.

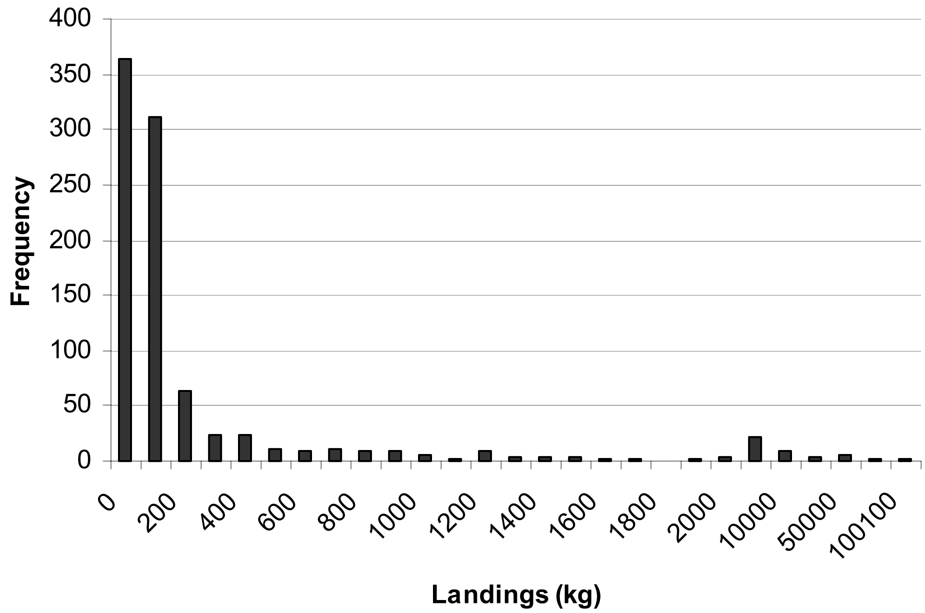


Figure B3. Distribution of landings of butterfish in otter trawls trips during 1989-2003.

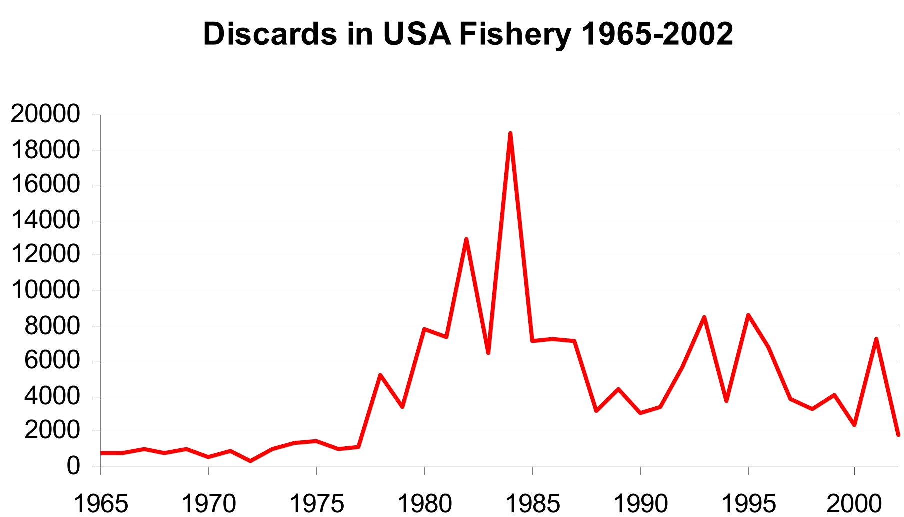


Figure B4. Estimated discards (mt) in the USA otter trawl fishery during 1965-2002.

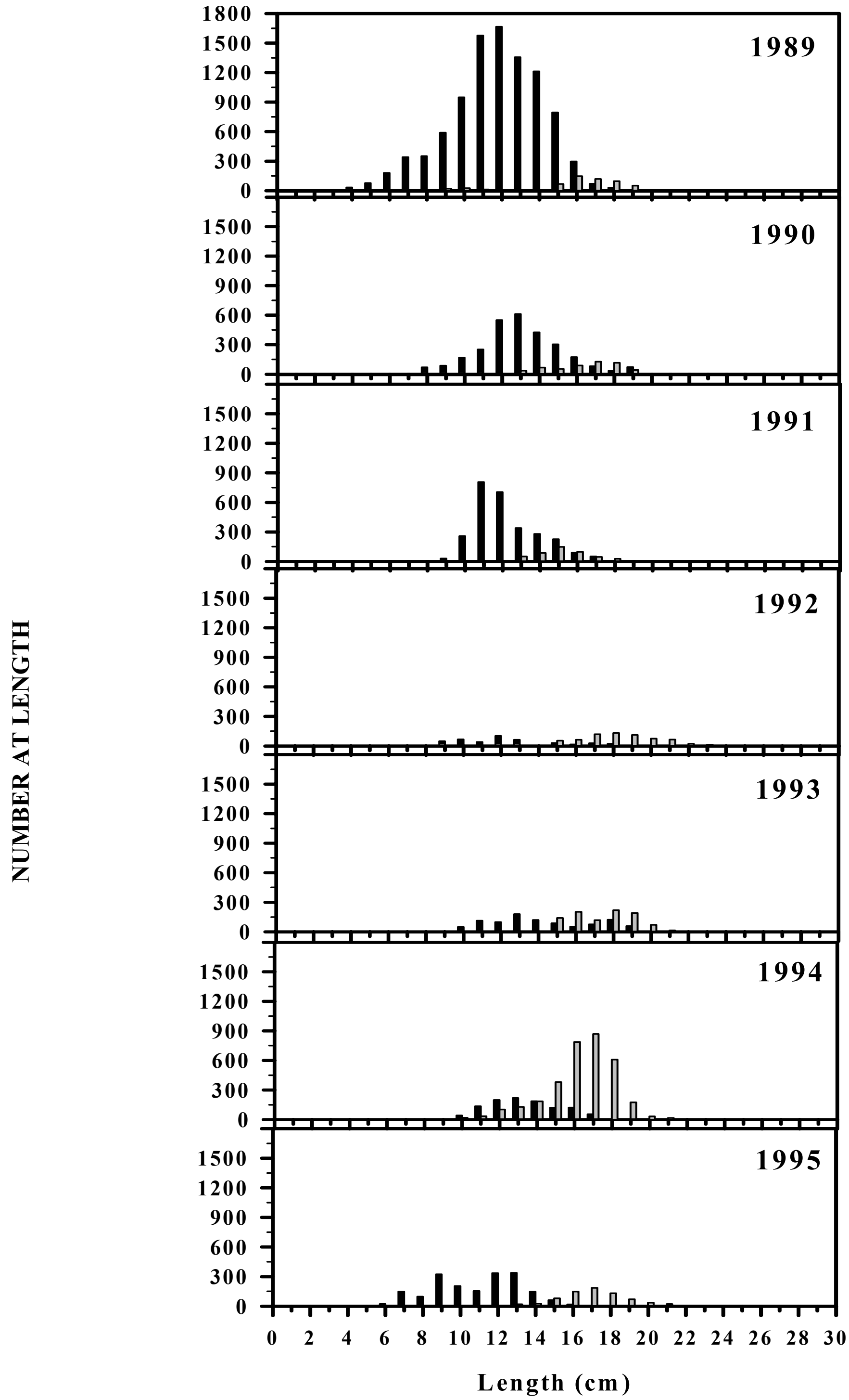
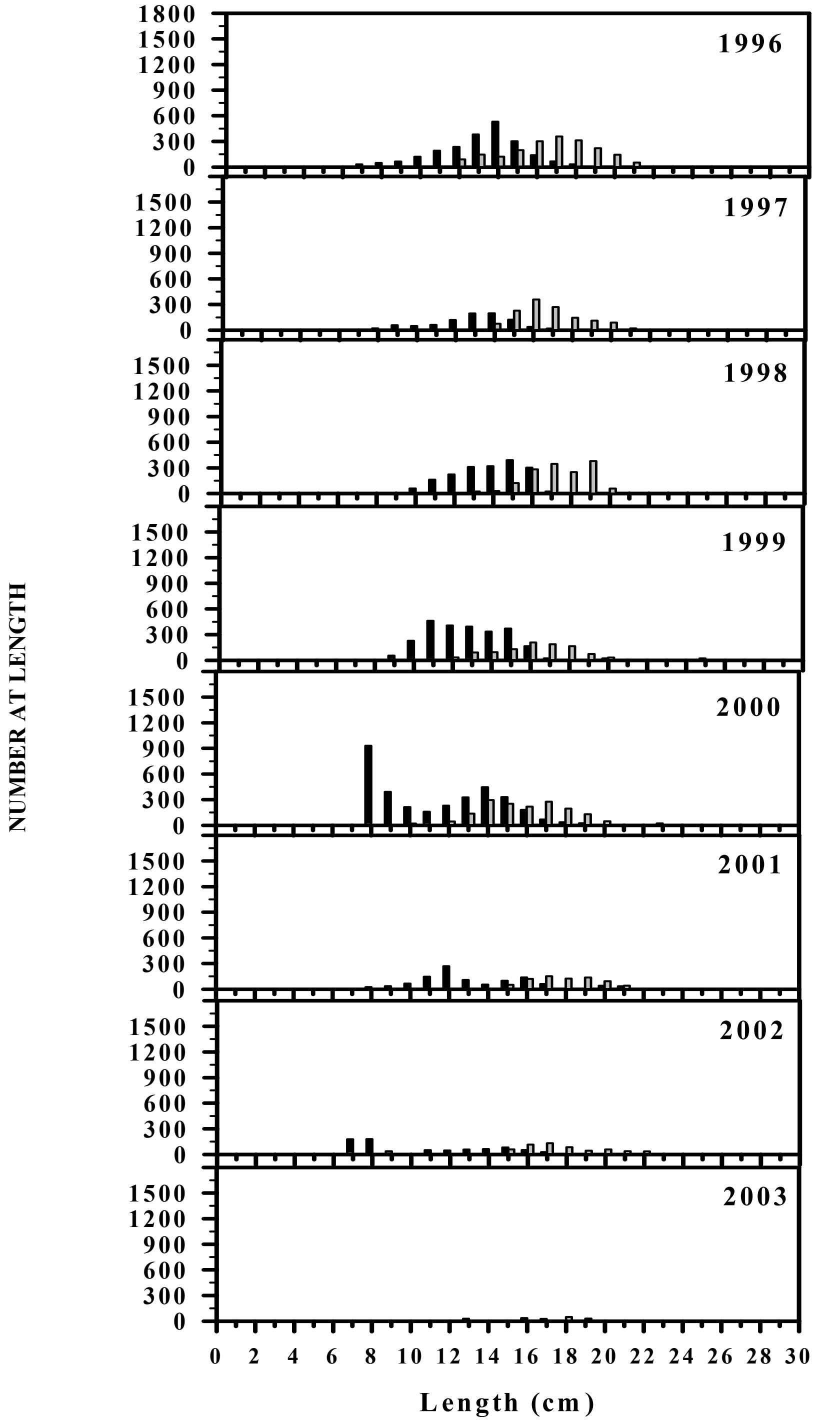


Figure B5. Length composition for NMFS Observer Program for butterfish during 1989-1995 with kept fish in gray and discard in black.

Figure B5. Continued, 1996-2003



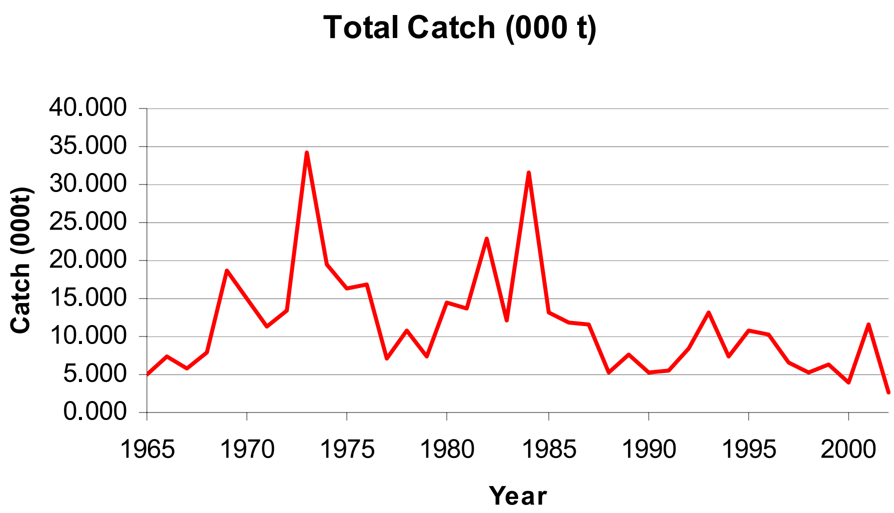


Figure B6. Total catch of butterfish during 1965-2002, includes USA landings, USA discards, and foreign landings.

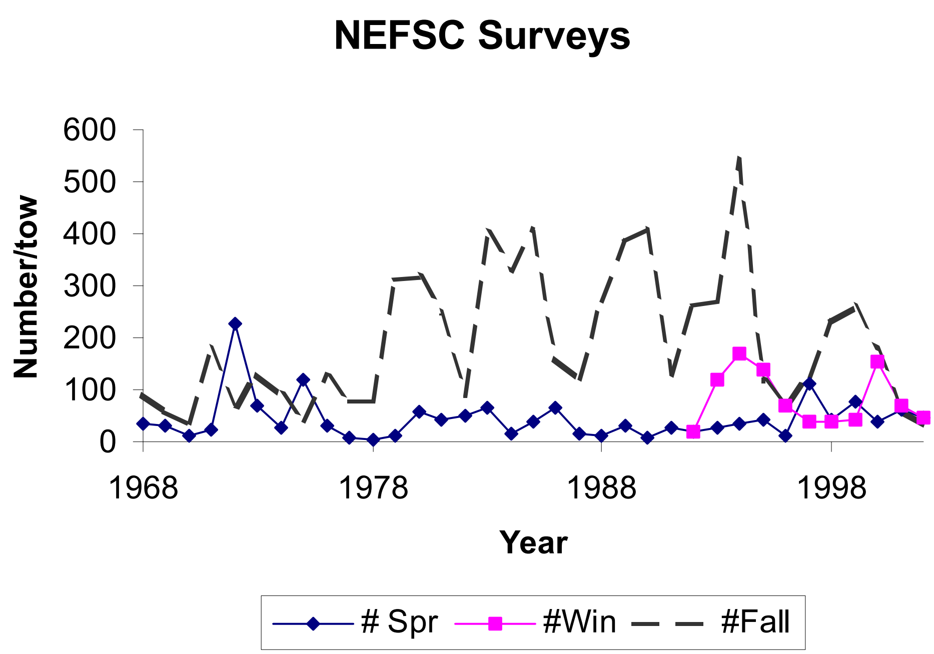


Figure B7. Research survey catch per tow in number for Winter 1994-2002, Spring 1968-2002, and Autumn 1968-2002 for NEFSC surveys for Strata 1-14, 16,19,23,25,61-76.

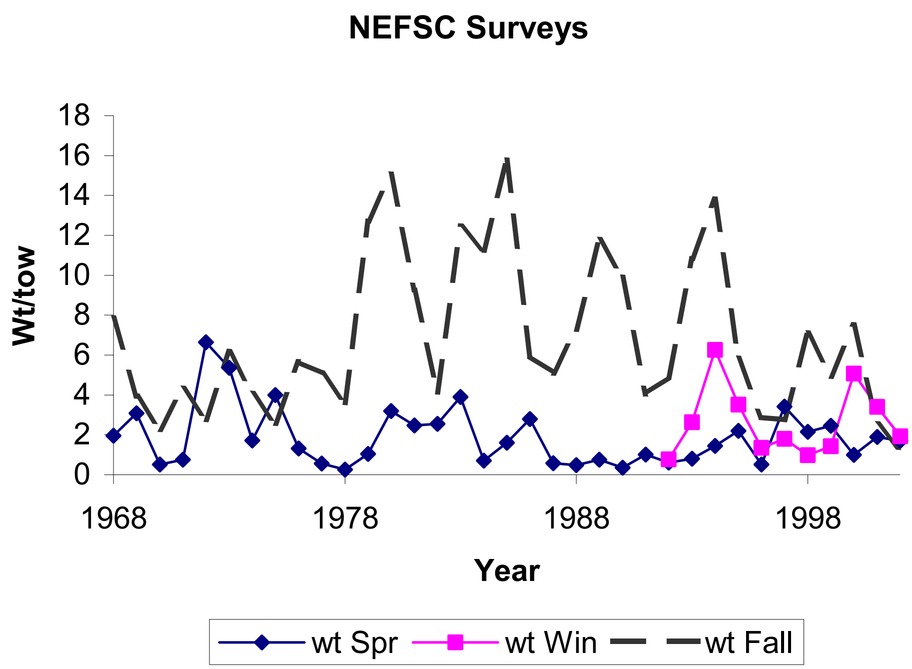


Figure B8. Research survey catch per tow (kg) for Winter 1994-2002, Spring 1968-2002, and Autumn 1968-2002 for NEFSC surveys for strata 1-14, 16,19,23,25,61-76.

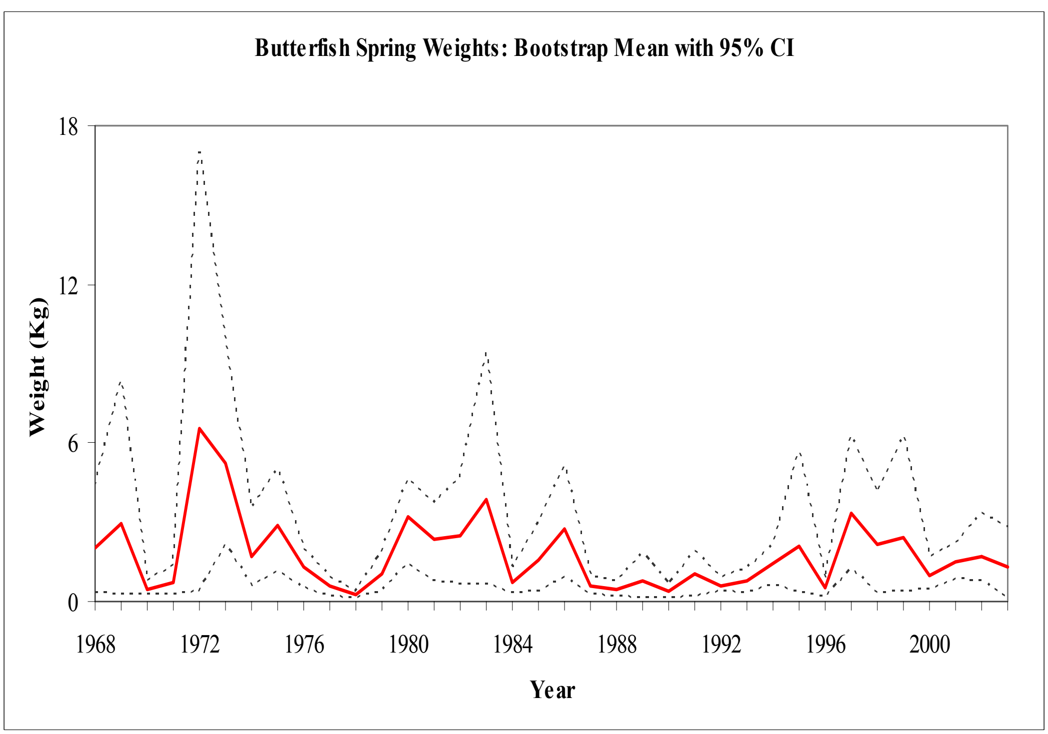


Figure B9. Catch in wt/tow and 95% confidence intervals (bootstrap analysis) for the spring NEFSC survey during 1968-2002.

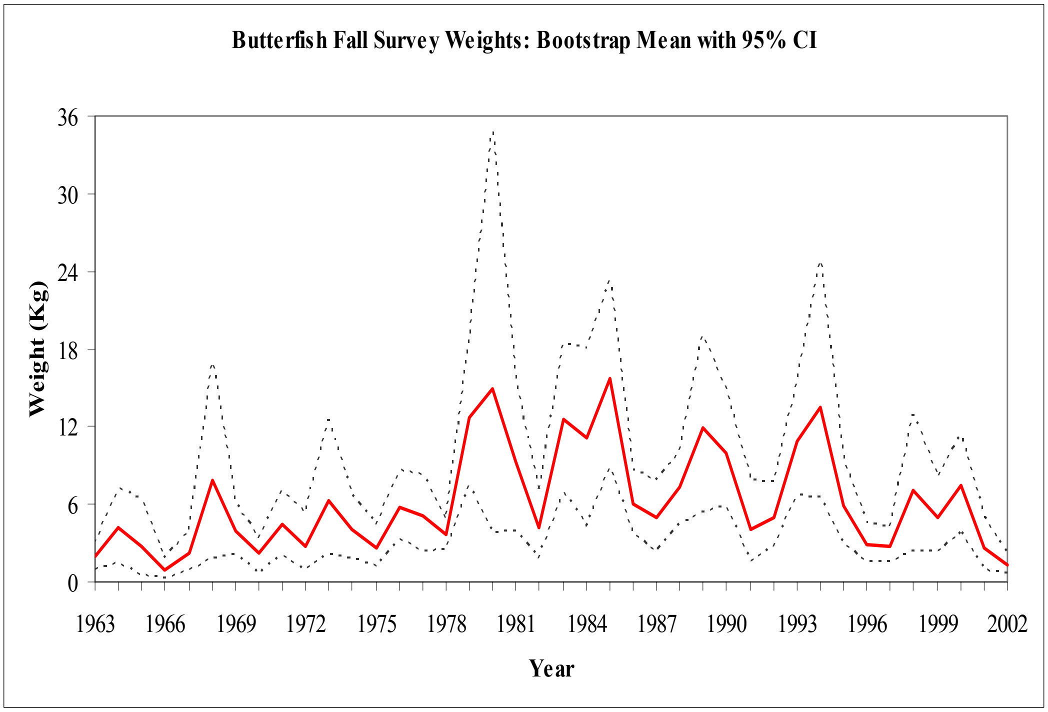


Figure B10. Catch in wt/tow and 95% confidence intervals (bootstrap analysis) for the fall NEFSC survey during 1968-2002.

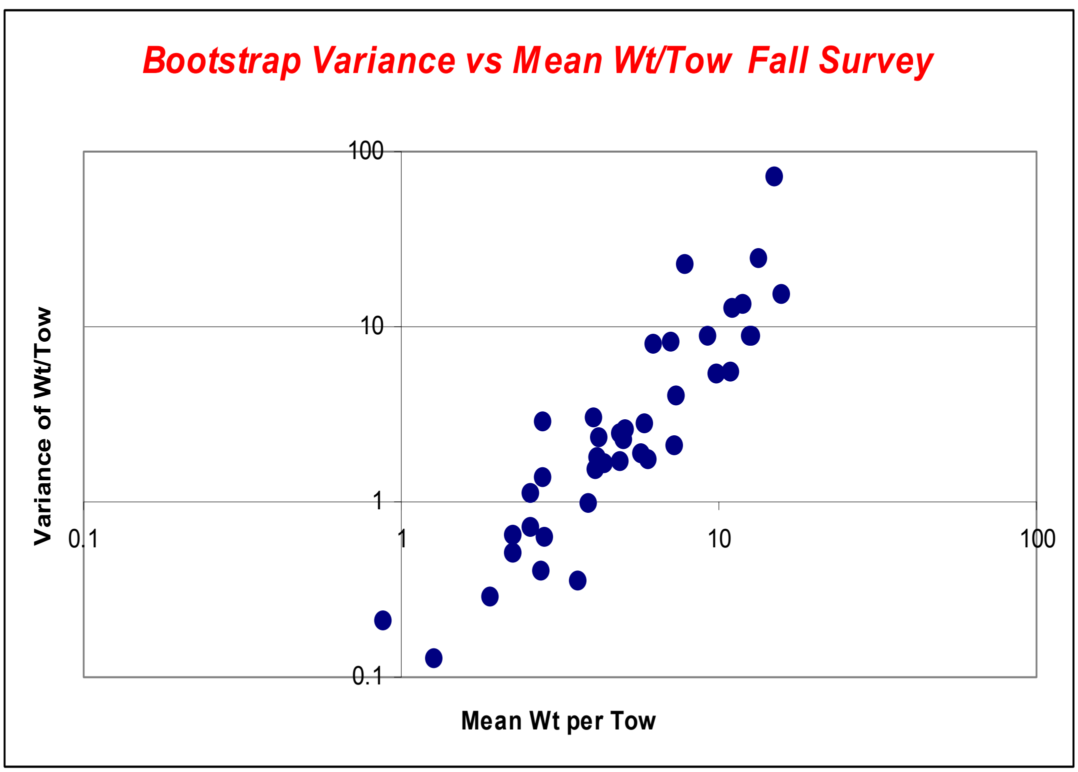


Figure B11. Relationship between fall survey wt/tow and variance in wt/tow during 1968-2002.

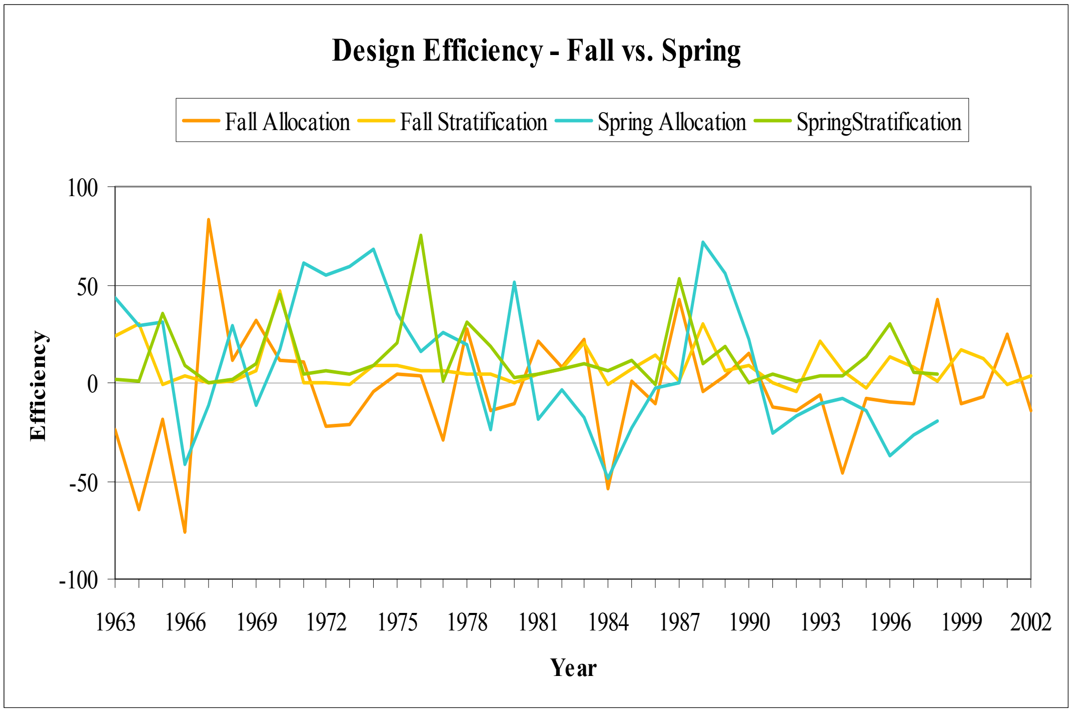


Figure B12. Design efficiency for stratification and allocation for the spring and fall NEFSC survey during 1963-2002.

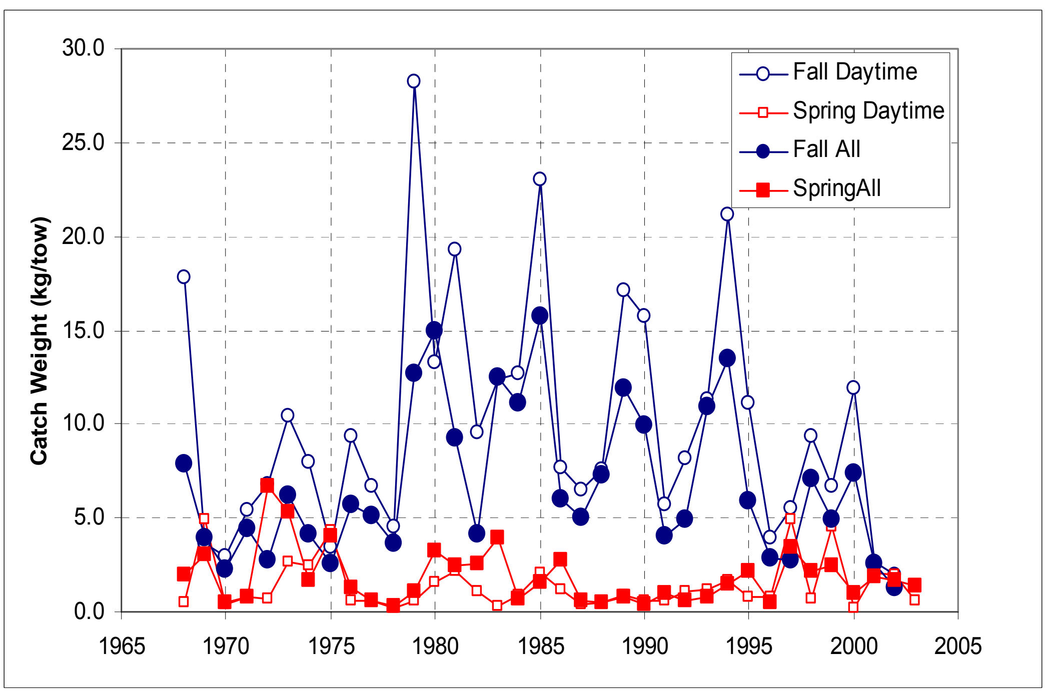


Figure B13. Spring and fall daytime and total wt/tow indices during 1968-2002.

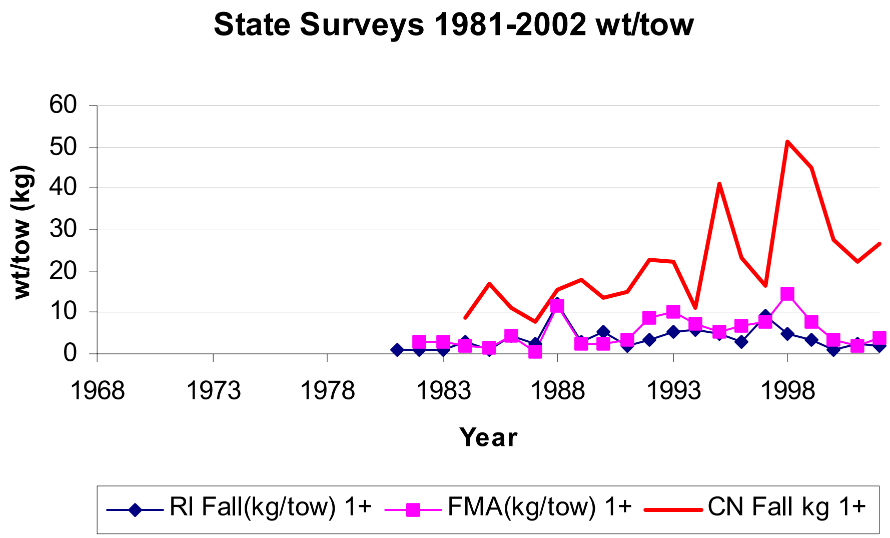


Figure B14. Catch-per-tow in weight for Rhode Island (1981-2002), Massachusetts (1982-2002), and Connecticut (1984-2002) bottom trawls surveys.

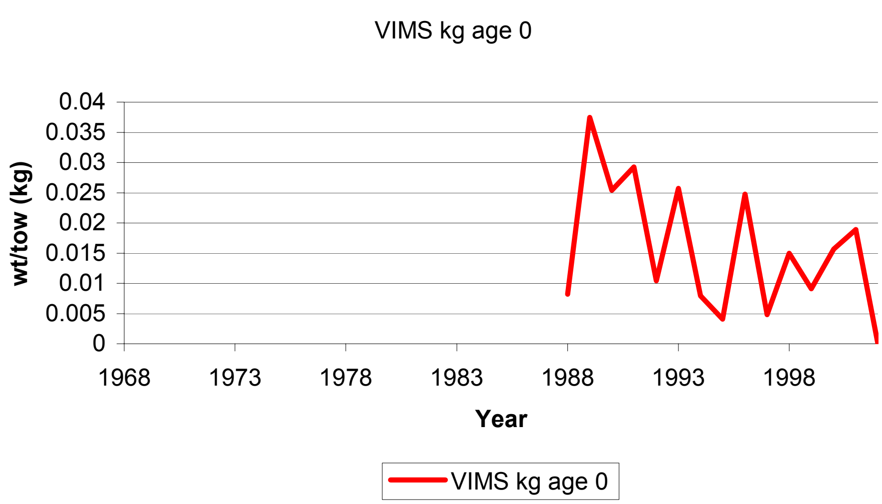


Figure B15. Catch-per-tow in weight for the VIMS bottom trawl survey age 0 during 1988-2001.

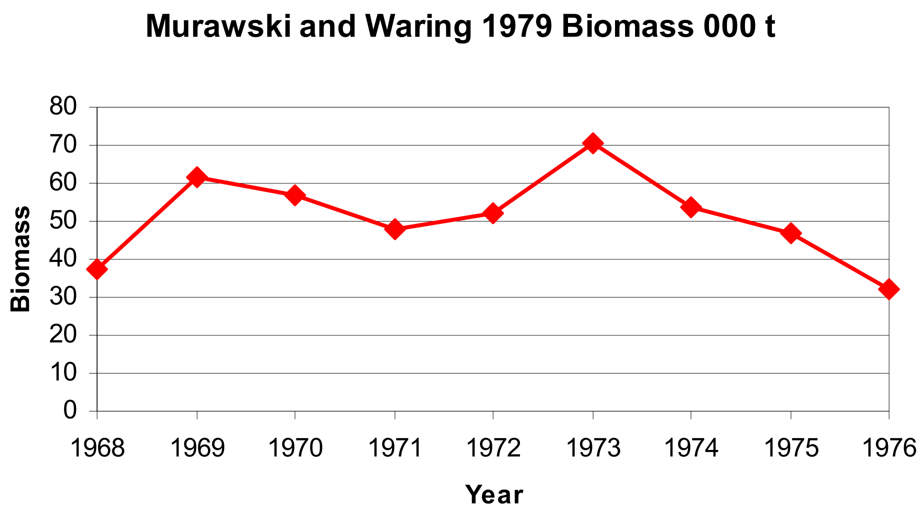


Figure B16. Estimates of butterfish biomass during 1968-1976 from VPA.

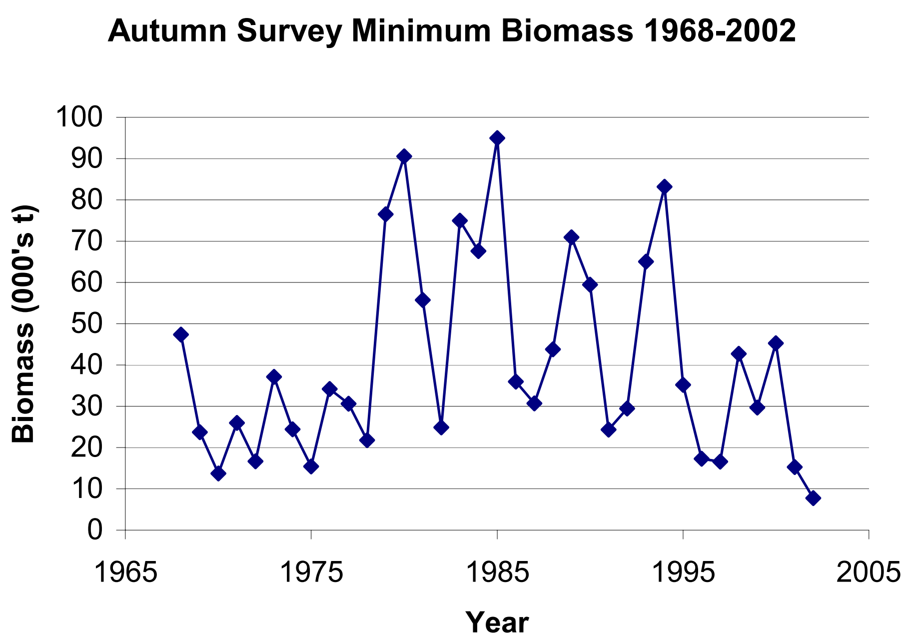


Figure B17. Autumn survey minimum swept area biomass during 1968-2002.

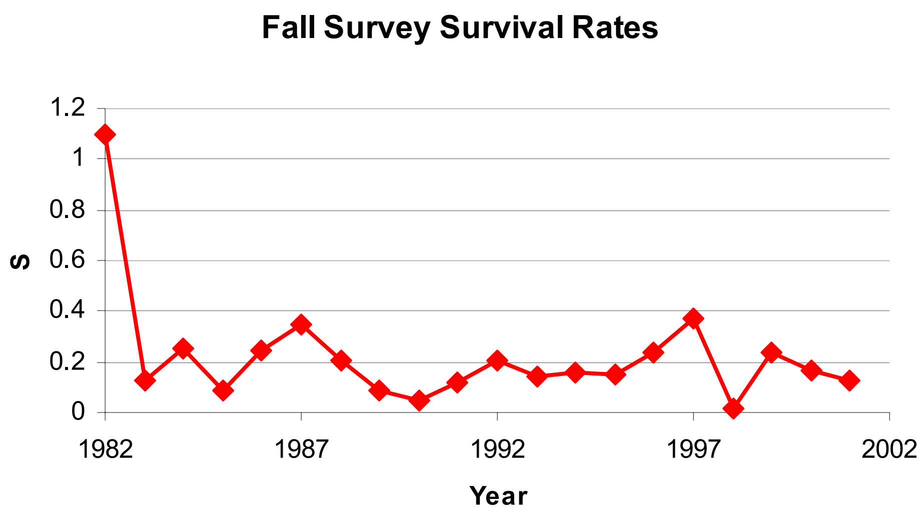


Figure B18. Survival estimates from autumn survey number/tow indices during 1982-2002.

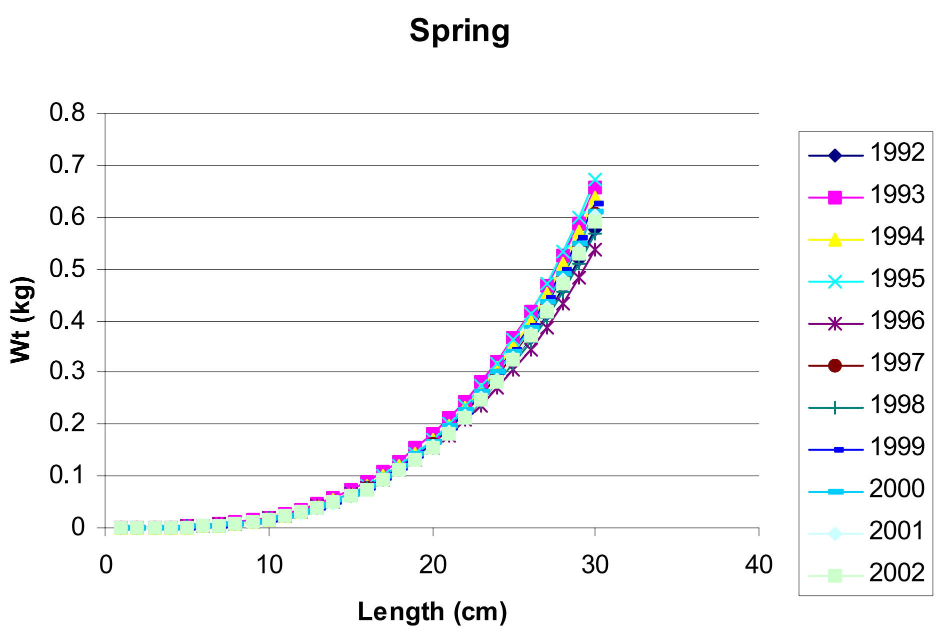


Figure B19. Length-Weight relationships for butterfish from spring bottom trawl surveys during 1992-2002.

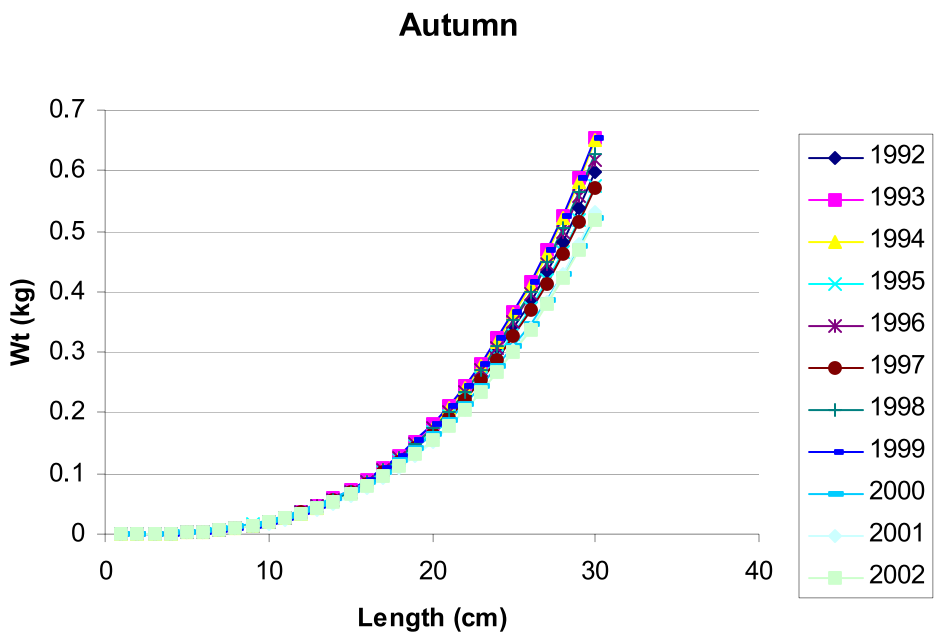


Figure B20. Length-Weight relationships for butterfish from autumn bottom trawl surveys during 1992-2002.

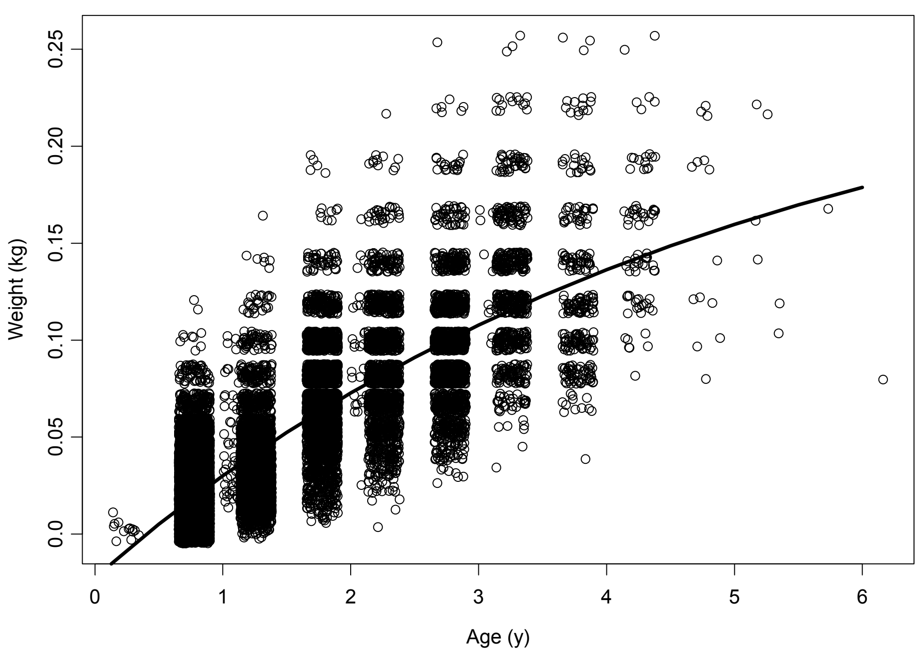


Figure B21. Von-Bertalanffy growth model fit to winter, spring, and Autumn NEFSC survey data from 1992-2003.

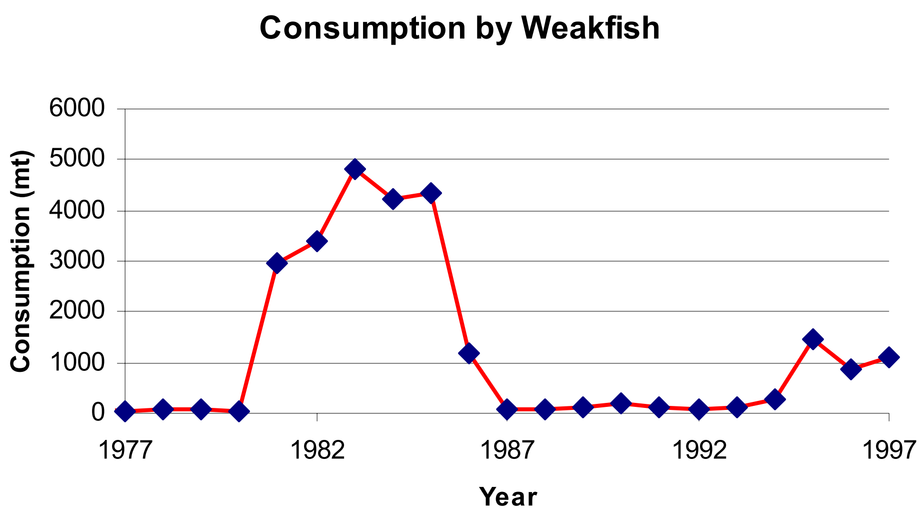


Figure B22. Consumption of butterfish (tonnes) by weakfish during 1977-1997.

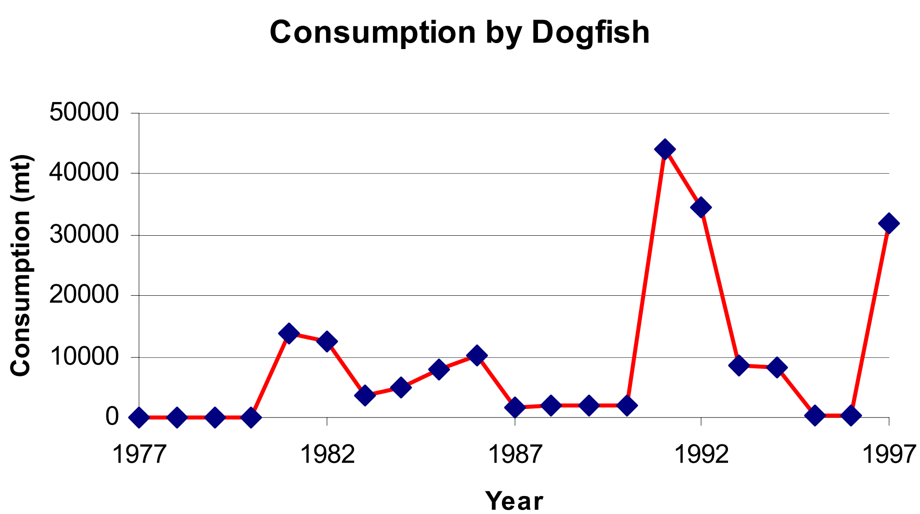


Figure B23. Consumption of butterfish (tonnes) by Spiny Dogfish during 1977-1997.

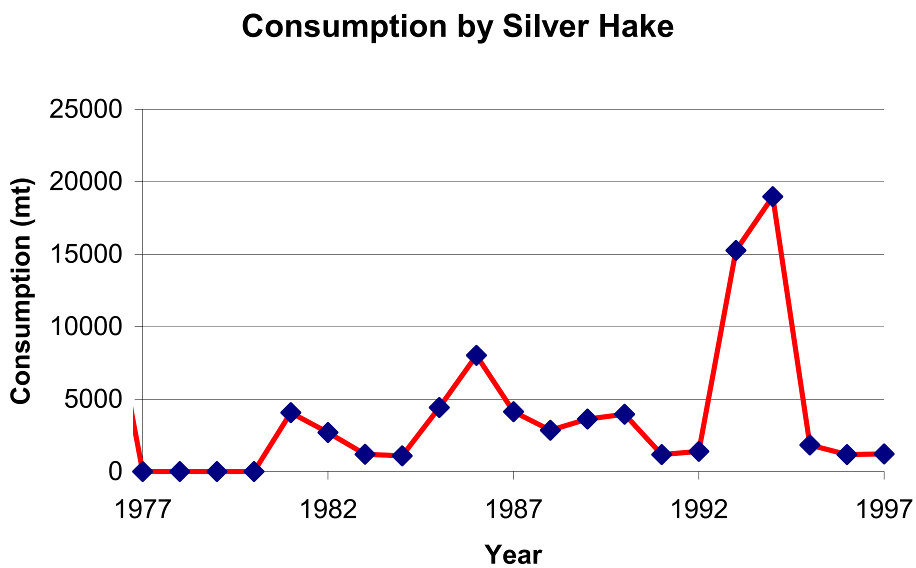


Figure B24. Consumption of butterfish (tonnes) by Silver Hake during 1977-1997.

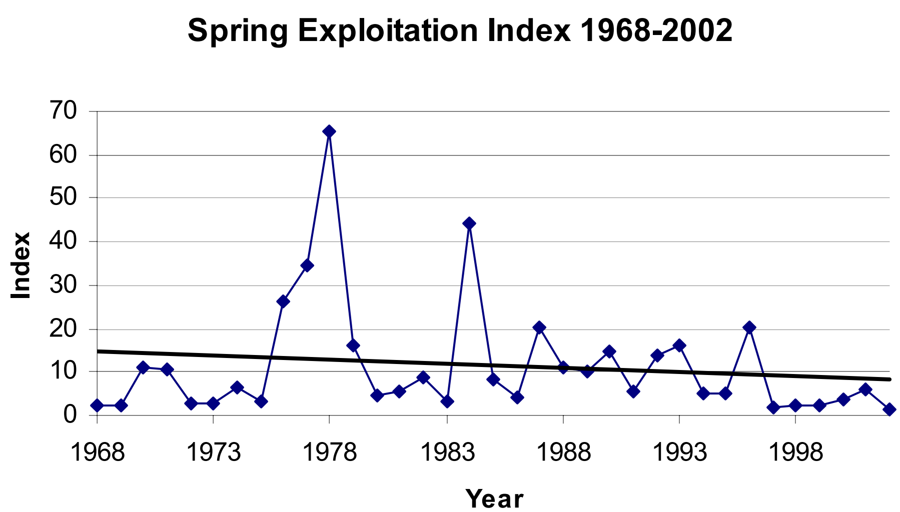


Figure B25. Exploitation indices for butterfish from the NEFSC Spring bottom trawl survey and catch during 1968-2002.

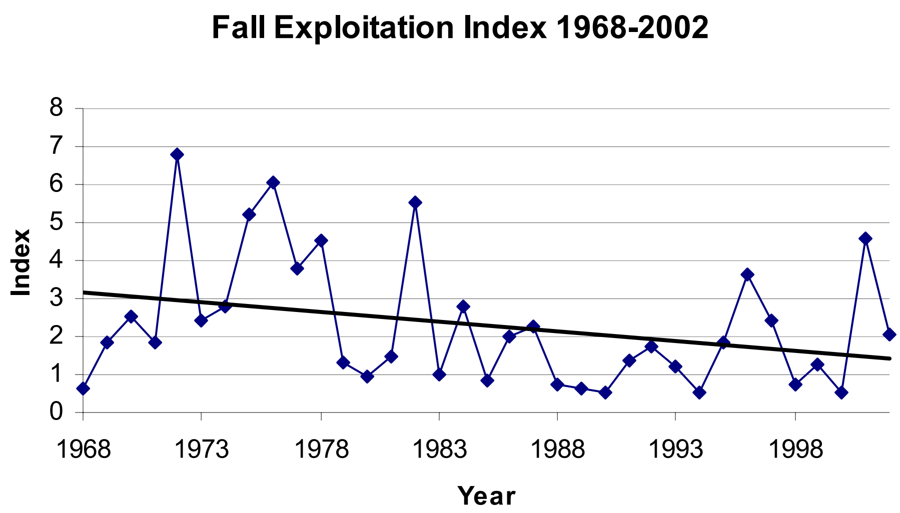
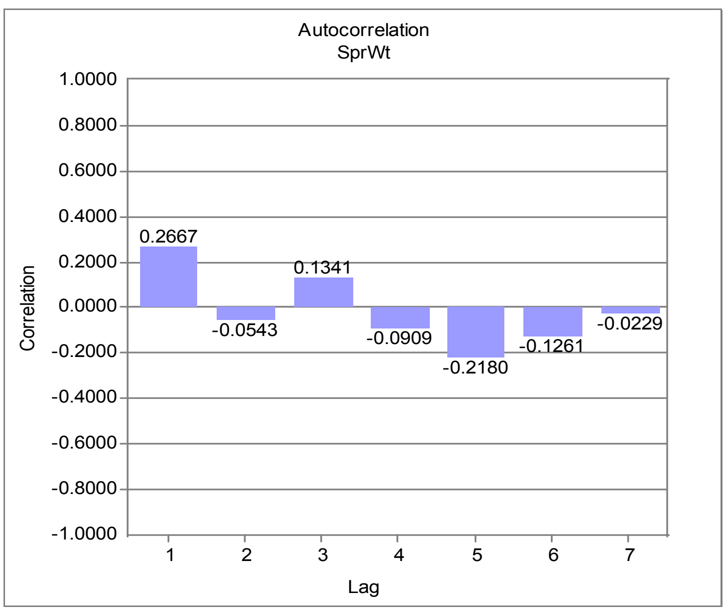


Figure B26. Exploitation indices for butterfish from the NEFSC Autumn bottom trawl survey and catch during 1968-2002.



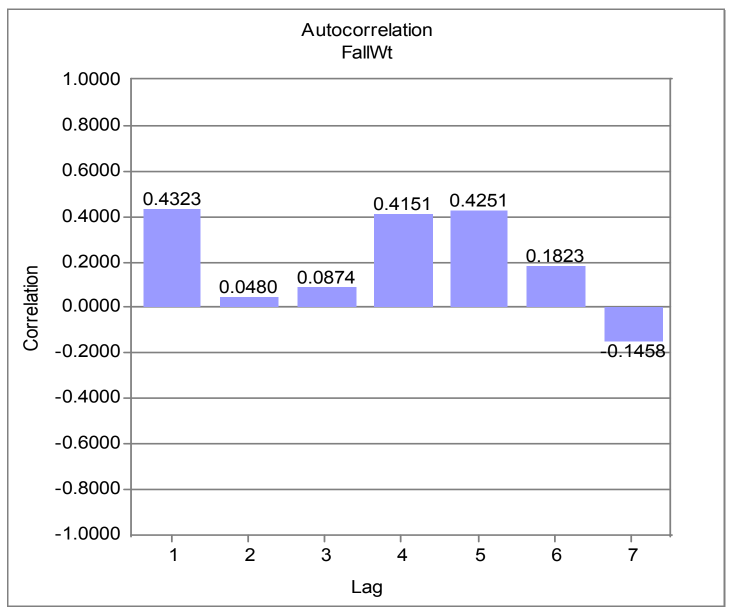


Figure B27. Autocorrelation plots for relationship between the replacement ratio and relative F for the spring and fall NEFSC surveys during 1968-2002.

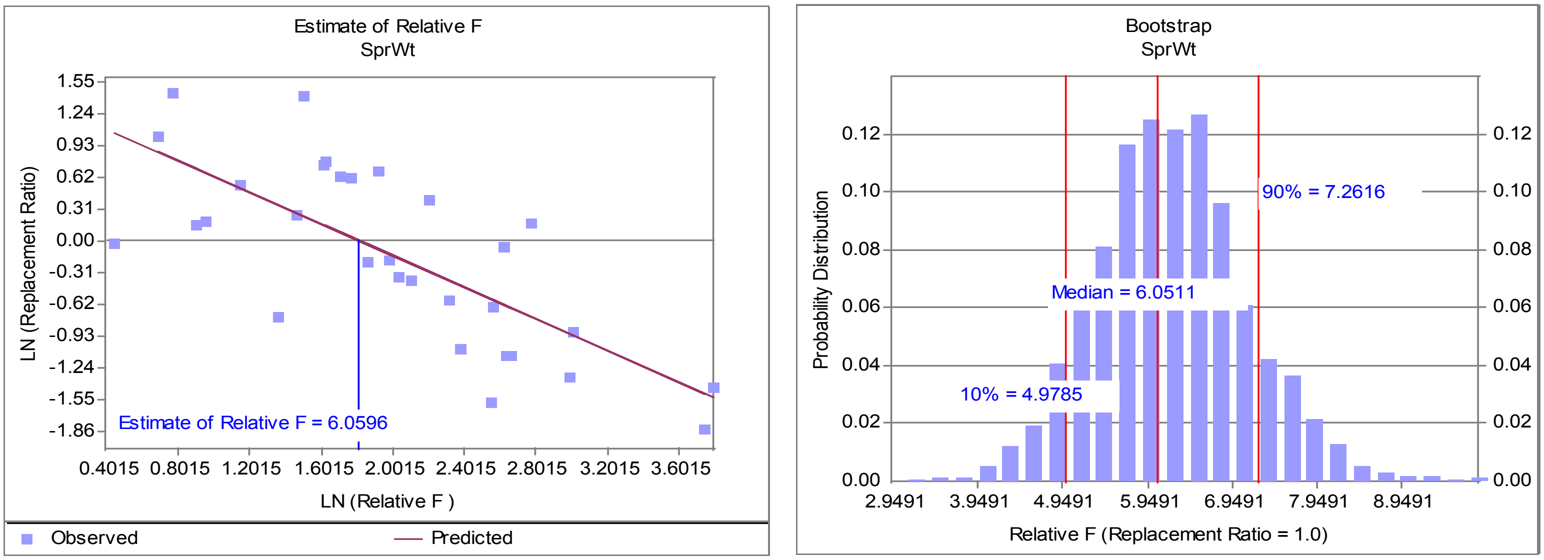


Figure B28. Plots of relative F and replacement ratio and bootstrap distribution of relative F for butterfish from the spring NEFSC survey during 1968-2002.

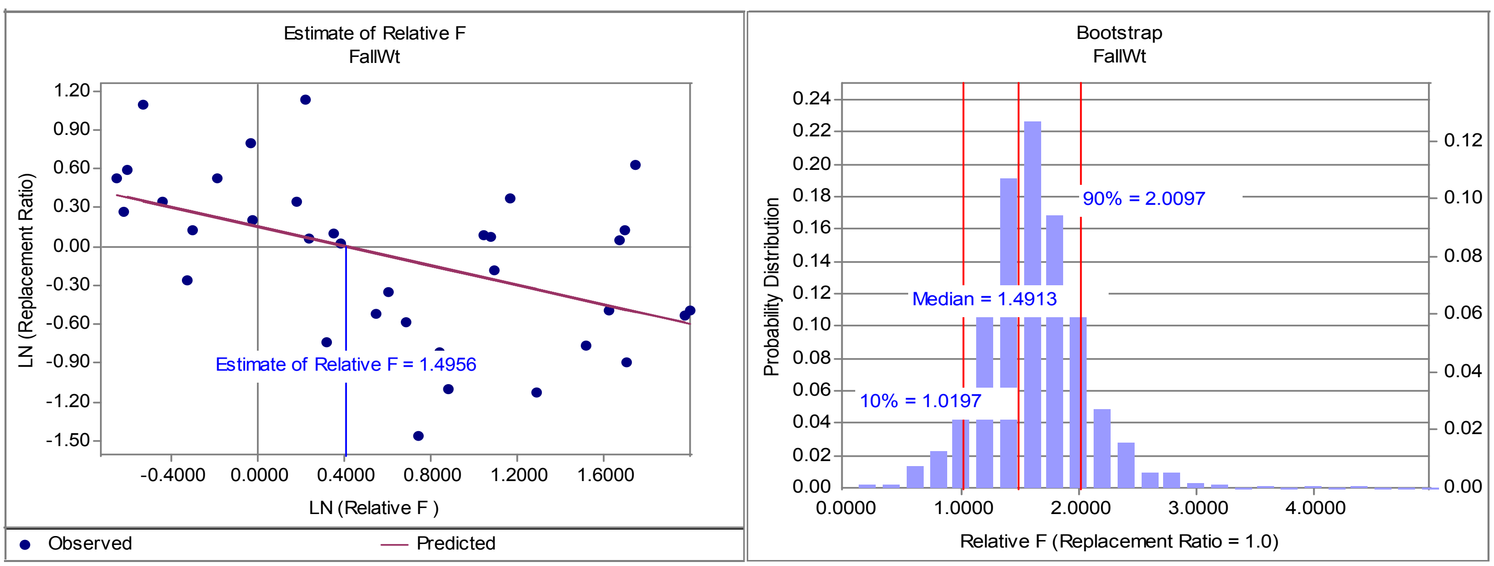


Figure B29. Plots of relative F and replacement ratios and bootstrap distribution of relative F for butterfish from the fall NEFSC survey during 1968-2002.

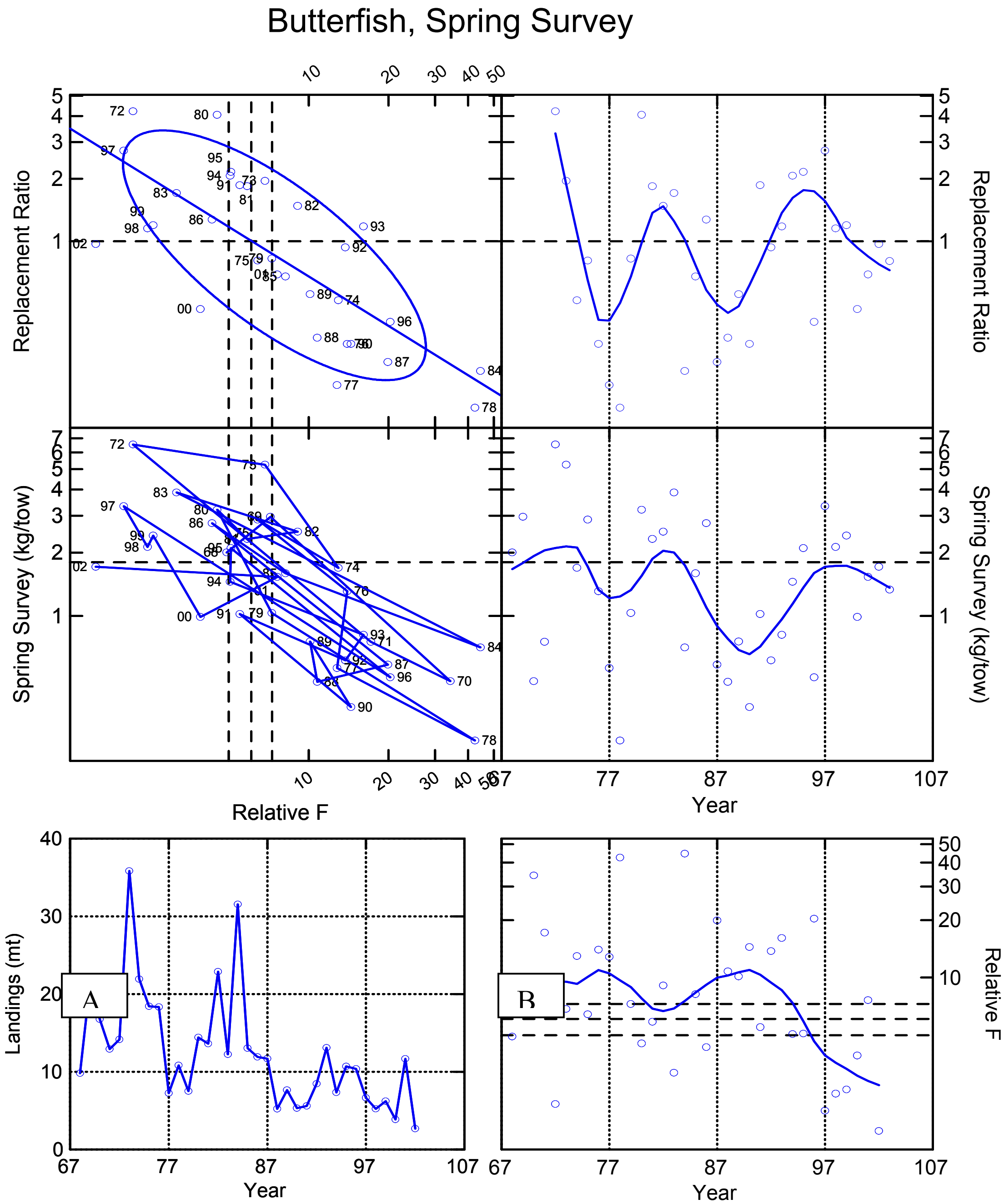


Figure B30. Six panel plot depicting trends in relative biomass, landings, relative fishing mortality rate (landings/abundance index) and replacement ratios for butterfish using NMFS spring bottom trawl survey. Lowess smooth lines are based on a tension factor of 0.3. Vertical dashed lines in panel A and C represent the point and 80% CI of relative F at replacement. Horizontal dashed lines in panel F represents same quantities. The horizontal line in panels C and D represent the arithmetic average of fall survey weight per tow (6.23 kg/tow).

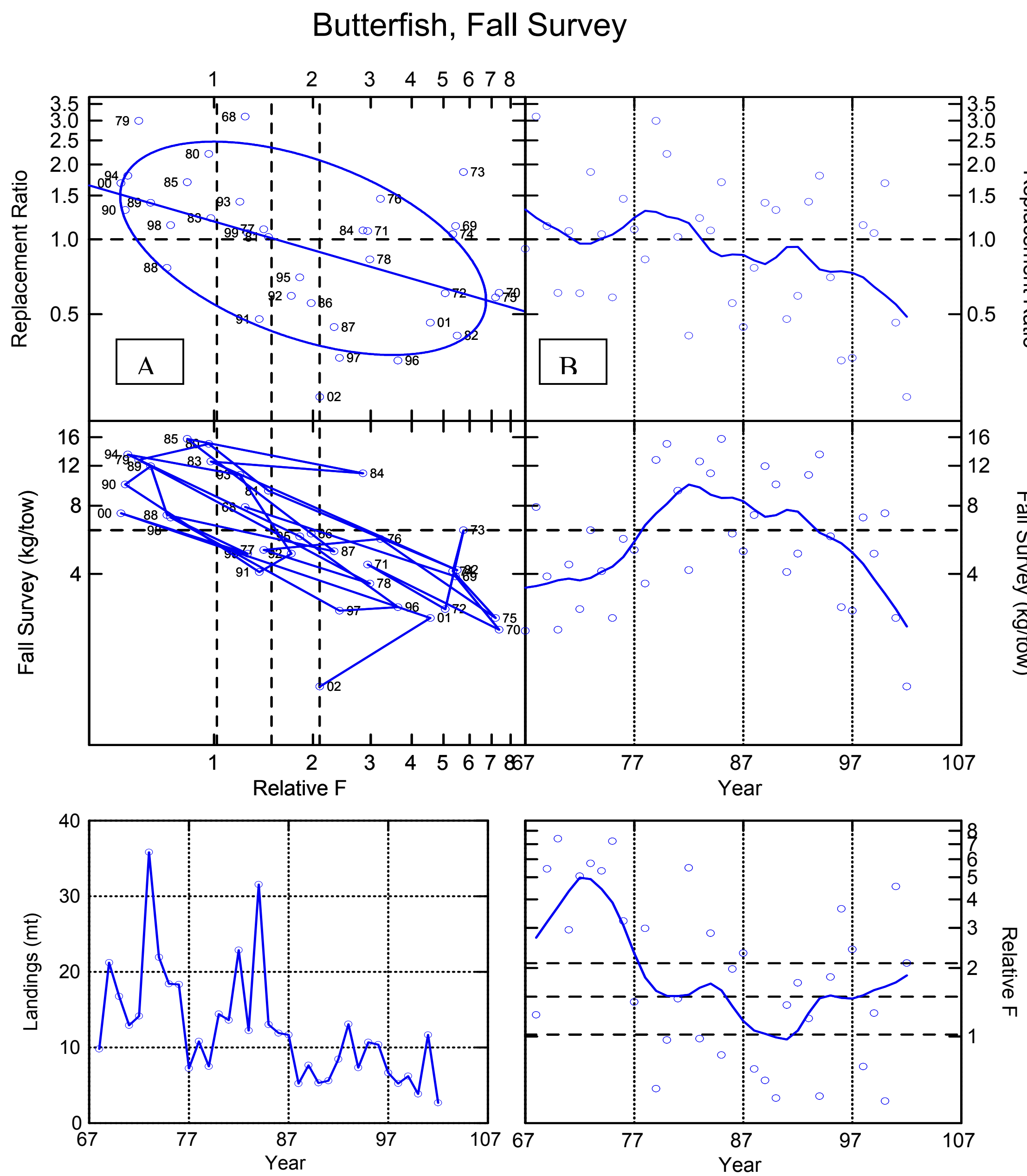


Figure B31. Six panel plot depicting trends in relative biomass, landings, relative fishing mortality rate (landings/abundance index) and replacement ratios for butterfish using NMFS fall bottom trawl survey. Lowess smooth lines are based on a tension factor of 0.3. Vertical dashed lines in panel A and C represent the point and 80% CI of relative F at replacement. Horizontal dashed lines in panel F represents same quantities. The horizontal line in panels C and D represent the arithmetic average of fall survey weight per tow (6.23 kg/tow).

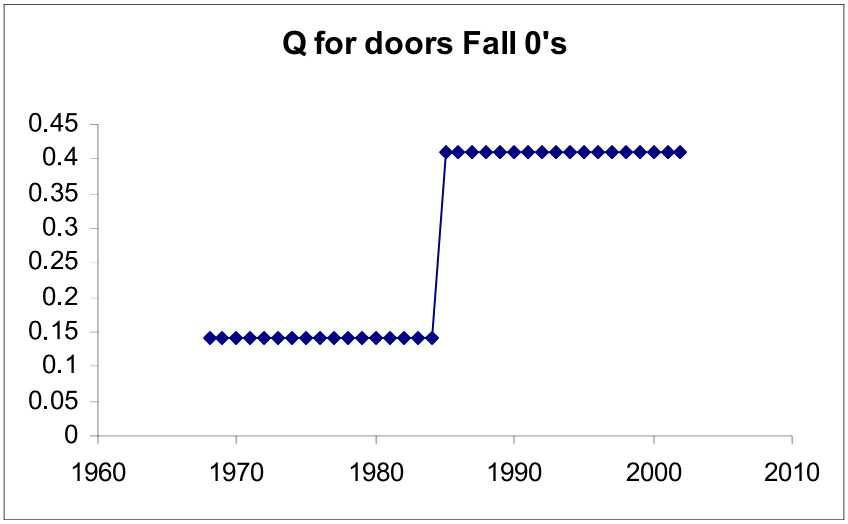


Figure B32. Q for the door adjustment that was estimated from a covariate that was added for the door conversion in 1985 for the fall age 0 index.

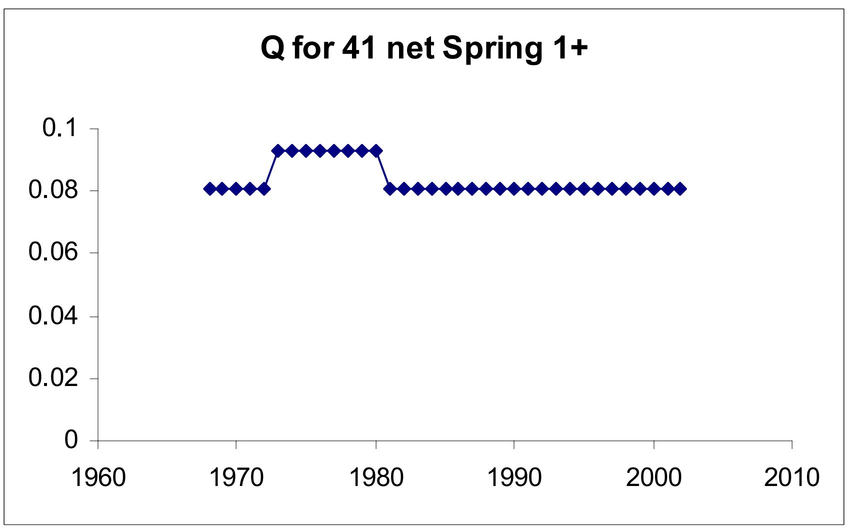


Figure B33. Q for the net adjustment that was estimated from a covariate that was added for the change in net that occurred during 1977-1981 for the spring age 1+ index.

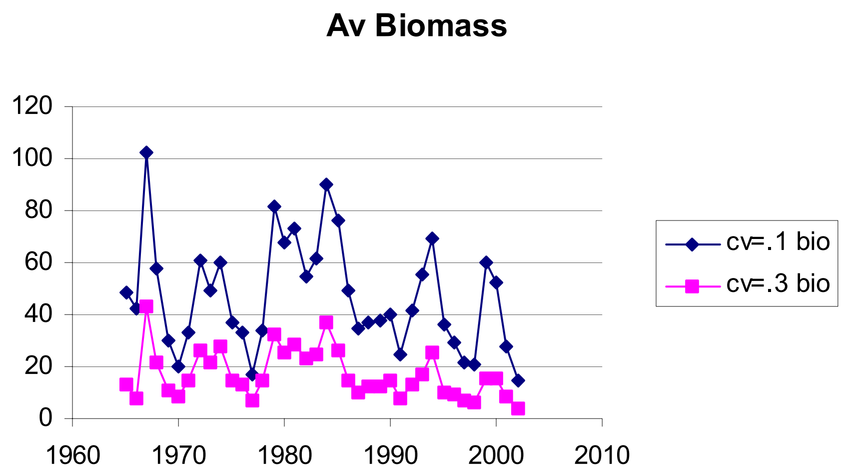


Figure B34. Average biomass for catch CV's of 0.1 and 0.3 during 1965-2002.

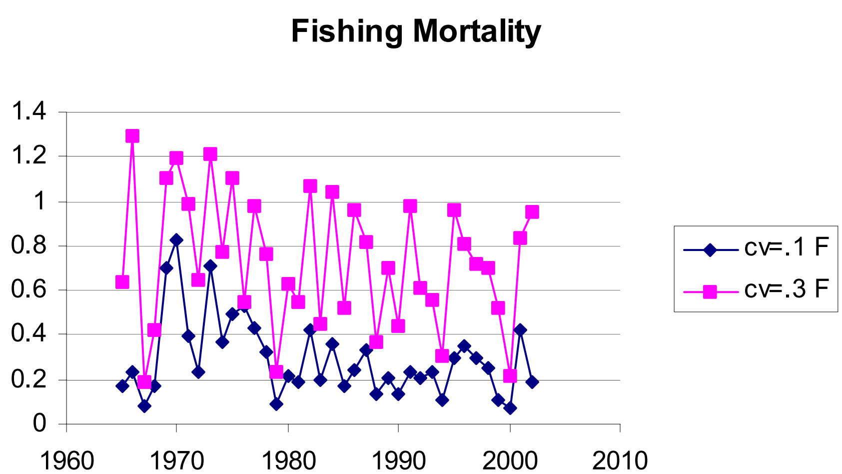


Figure B35. Fishing Mortality for catch CV's of 0.1 and 0.3 during 1965-2002.

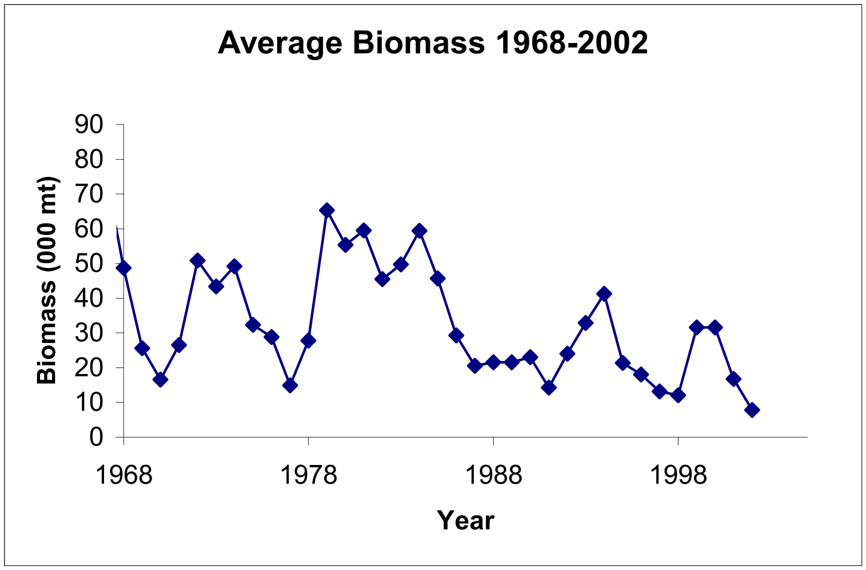


Figure B36. Average biomass of butterfish during 1968-2002.

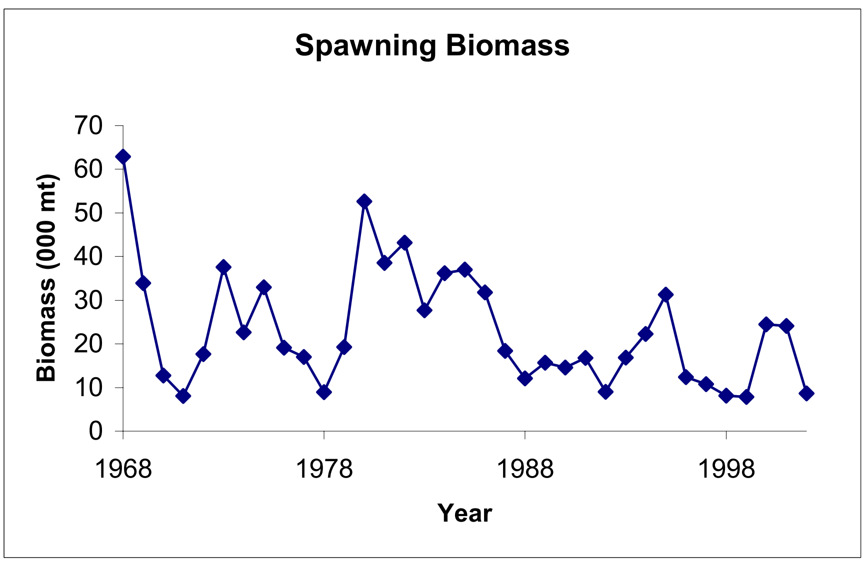


Figure B37. Spawning biomass of butterfish during 1968-2002

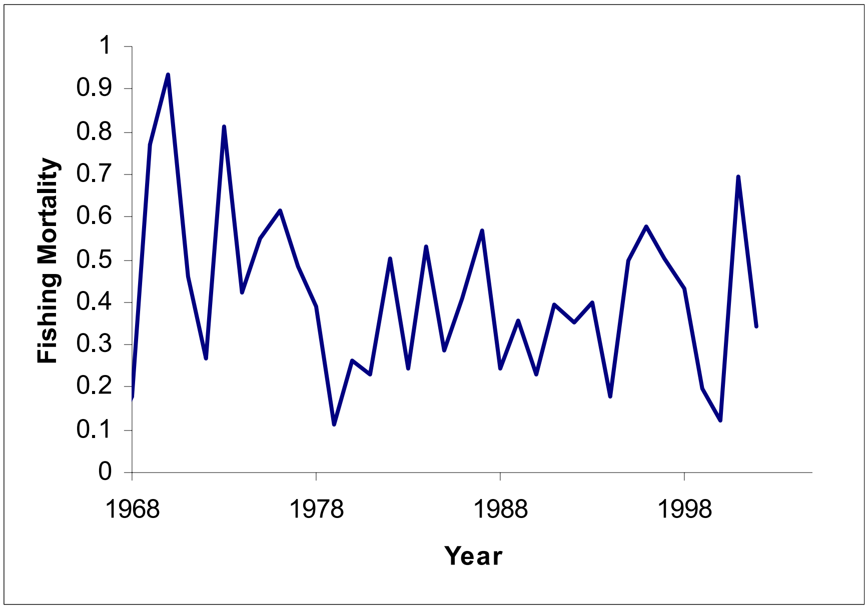


Figure B38. Fishing mortality rates on the butterfish stock during 1968-2002.

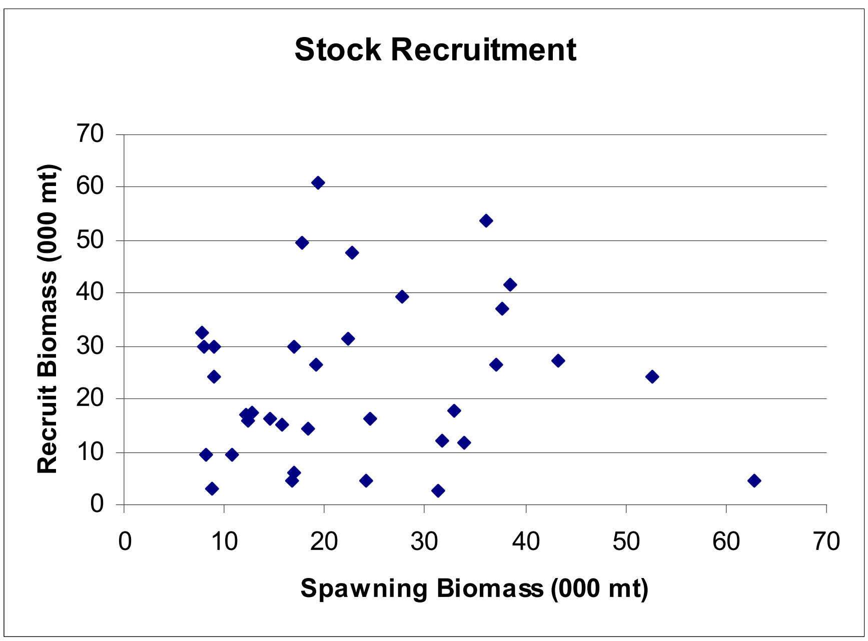


Figure B39. Spawning stock biomass and recruitment biomass (000's t) during 1968-2002.

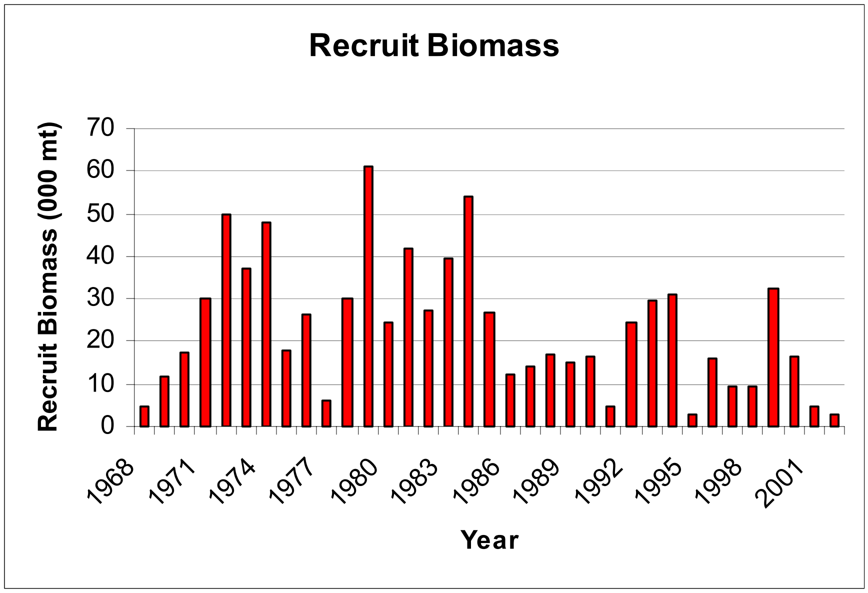


Figure B40. Recruit biomass of butterfish during 1968-2002.

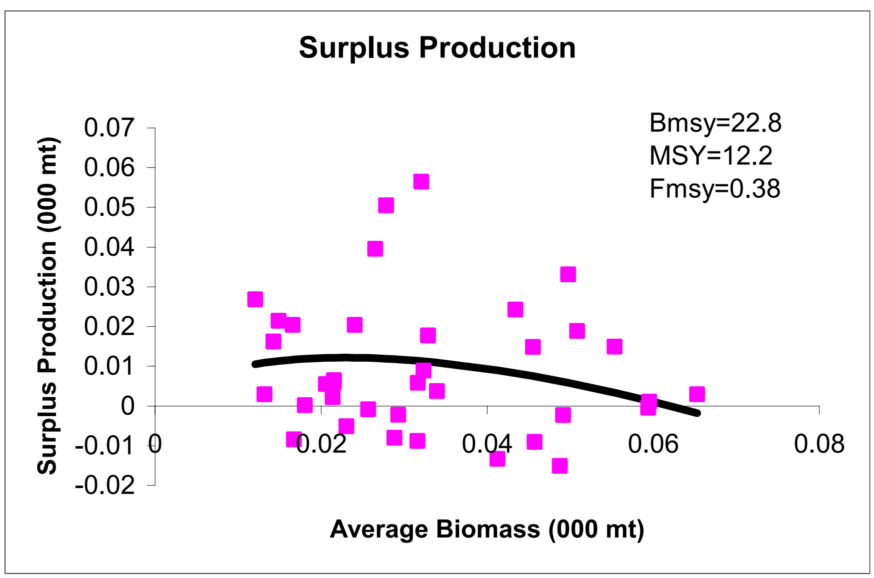


Figure B41. Average biomass and surplus production for butterfish during 1968-2002.

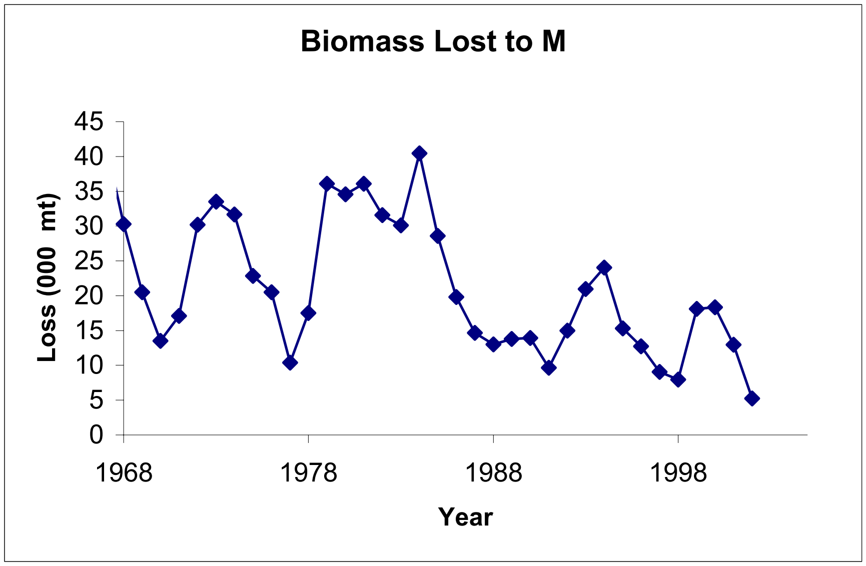


Figure B42. Biomass lost to natural mortality, all sources, during 1968-2002.

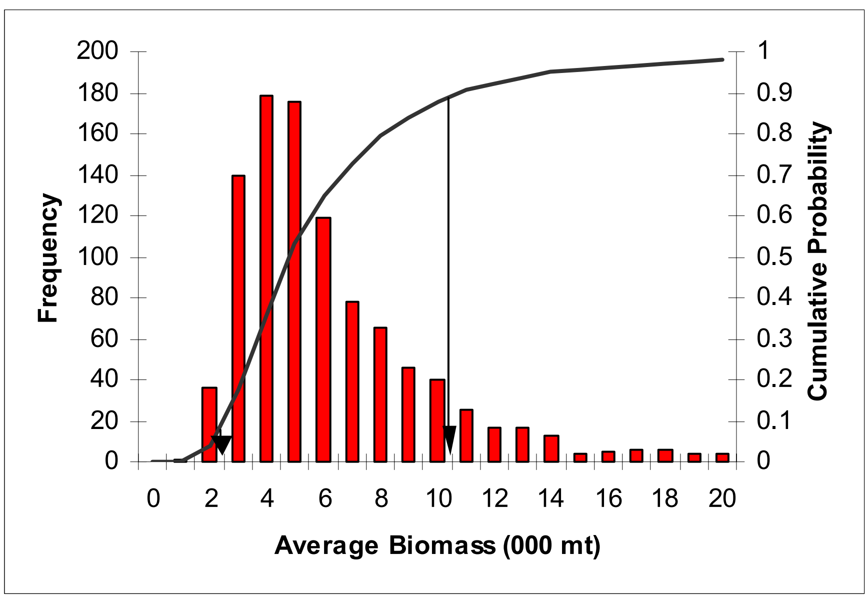


Figure B43. Estimates of precision and 80% CI of average biomass in 2002.

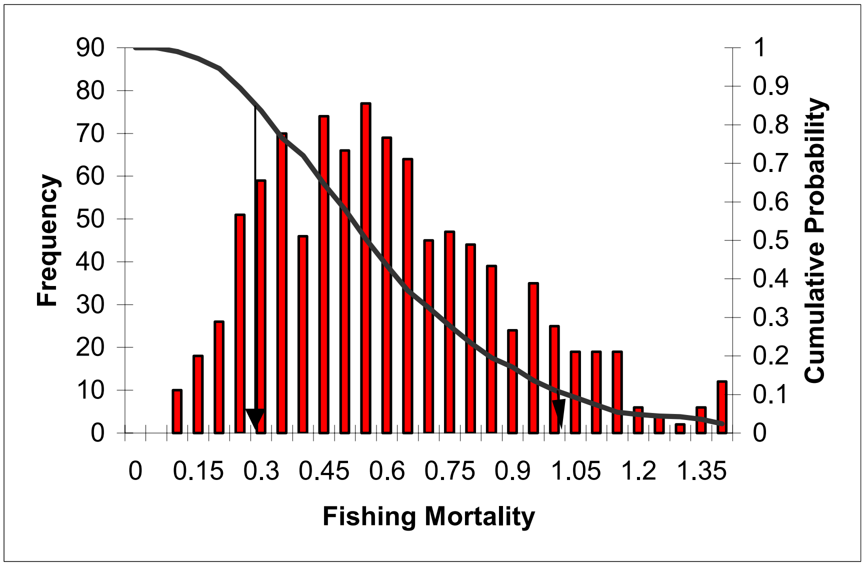


Figure B44. Estimates of precision and 80 % CI of Fishing Mortality I.

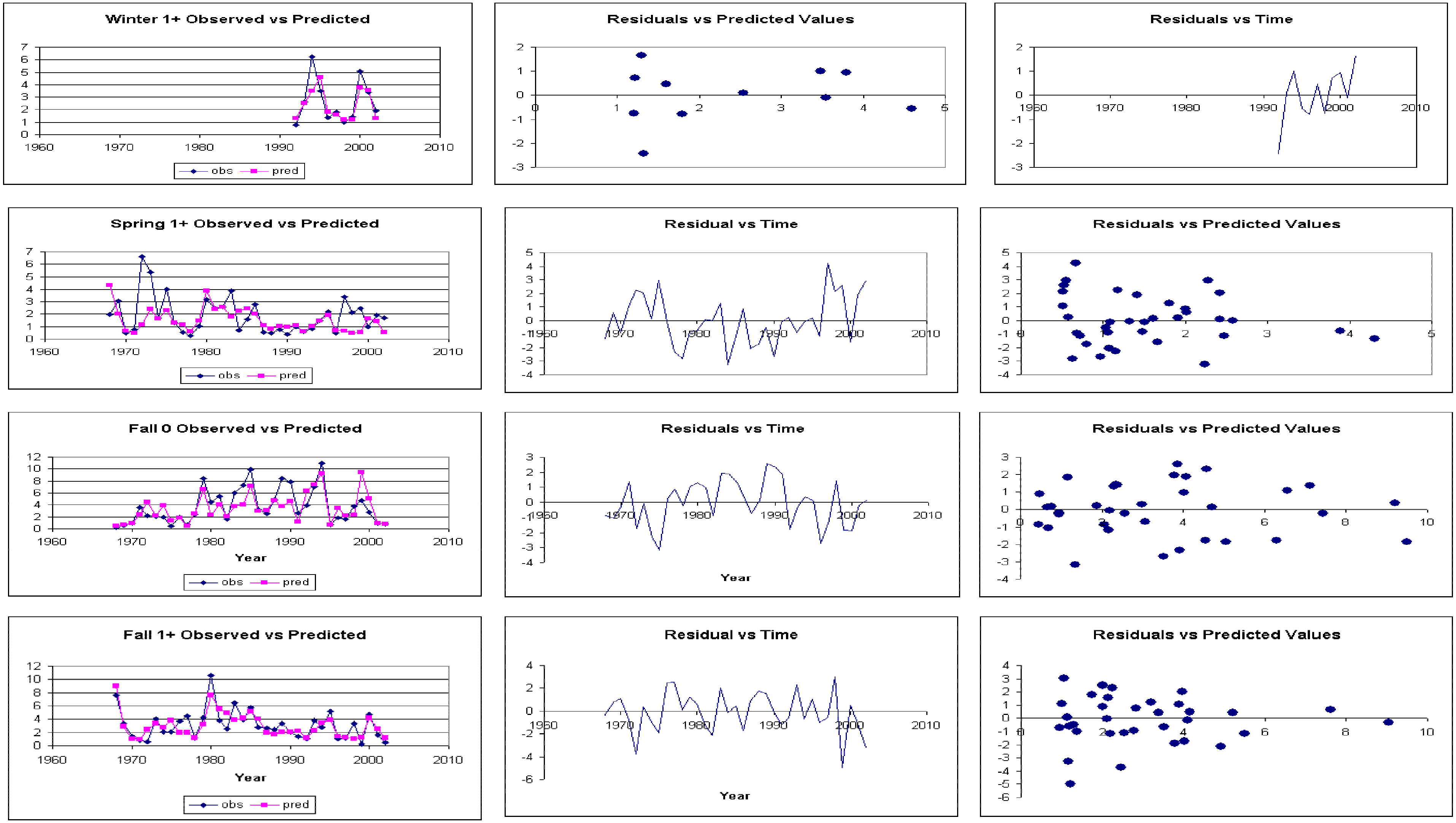


Figure B45. Plots of observed vs. predicted, residual vs. time, and residuals vs. predicted for winter 1+, spring 1+, and fall 0 and 1+ during 1968-2002.