B. ATLANTIC MACKEREL STOCK ASSESSEMENT

TERMS OF REFERENCE

1. Characterize the commercial and recreational catch including landings and discards.
2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.
3. Evaluate and either update or re-estimate biological reference points, as appropriate.
4. As needed by management, estimate a single-year or multi-year TAC and/or TAL by calendar year or fishing year, based on stock biomass and target mortality rate.
5. If possible,
   a. provide short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies and
   b. evaluate current and projected stock status against existing rebuilding or recovery schedules, as appropriate.
6. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in previous SARC-reviewed assessments

EXECUTIVE SUMMARY

(TOR 1) Atlantic mackerel were heavily exploited by distant water fleets during the 1970's. Total landings in NAFO subareas 2-6 averaged 350,000 mt during 1970-1976, but this level was not sustainable (Figure B1). Annual landings decreased to less than 50,000 mt during 1978-1984. Landings in Canada remained relatively constant at an average of 24,000 mt during 1968-2000. Landings in the US EEZ increased during 1985-1991 to an average of 76,000m t, with the advent of a JV fishery in the Mid-Atlantic region. More recently landings by both the USA and Canada have increased as world demand has improved. Commercial landings in the U.S. increased from a low of 5,646m t in 2000 to 53,724 mt in 2004, while landings in Canada increased form 13,383 mt in 2000 to 51,444 mt in 2004. Recreational landings of mackerel in the USA averaged 1,344 mt during 1990-2000, but decreased from 1,538m t in 2001 to only 467 mt in 2004.

The northwest Atlantic mackerel stock is not overfished and overfishing is not occurring relative to the new reference points from this assessment. (TOR 2) Fishing mortality has remained low for the last decade, but increased slightly from 0.02 in 2002 to 0.05 in 2004. The confidence interval (± 2 SD) for F in 2004 ranged from 0.035 to 0.063, but retrospective analysis shows that

F has sometimes been underestimated in recent years. The overfishing reference point, Fmsy, was re-estimated at Fmsy=0.16 (previously Fmsy=0.45).

(TOR 2) Spawning stock biomass increased steadily over the last several decades from a low of 663,000 t in 1976 to 2.3 million mt in 2004. The confidence interval on SSB ($\pm$ 2 SD) ranged from 1.49 to 3.14 million mt in 2004; however, retrospective analysis showed that SSB has sometimes been overestimated in recent years. The biomass reference point was re-estimated in this assessment at SSBmsy= 644,000 mt (previously SSBmsy=890,000 mt).

(TOR 3) Fishing mortality based biological reference points (BRP's) were re-estimated during SARC 42. Fishing mortality reference points are $F_{0.1}$ = 0.25 and $F_{40\%}$ = 0.24. Reference points from model estimated B-H parameters are MSY = 89,000 mt, SSBmsy = 644,000 mt, and Fmsy = 0.16. Surplus production in the mackerel stock was available sporadically during 1962-2004. Periods of positive SP occurred before the ICNAF fishery in the late 1960s, during the early 1980s, and more recently in the late 1990s through 2003. The average SP available during 1962-2003 was 148,000 mt; this can serve as a proxy upper bound on MSY for the current assessment. Stock-recruitment BRP's were estimated prior to SARC 30 using a bootstrap method as Fmsy=0.45, F target=0.25, MSY=326,000 mt, and SSBmsy=887,000 mt (NEFMC 1998); these should be replaced with the more current values.

(TOR 4, 5) Deterministic projections for 2006-2008 were conducted by inputting an estimated catch of 95,000 mt in 2005 and a target fishing mortality of 0.12 (MAFMC 1998, Ftarget=0.75 x Fmsy) in 2006-2008. If 95,000 mt are landed in 2005, SSB in 2006 will increase to 2.6 million mt. If the Ftarget F=0.12 is attained in 2006-2008, SSB will decline to 2.3 million mt in 2007 and to 2.0 million mt in 2008. Landings during 2006-2008 would be 273,000 mt, 239,000 mt, and 212,000 mt, respectively. These landings are the result of an unusually large year-class (1999) present in 2005, and will not be sustainable in the long term. It is expected that these projected landings will decline to MSY (89,000 mt) in the future when a more average recruitment condition exists in the stock.

1.0 INTRODUCTION

Atlantic mackerel (*Scomber scombrus*) are distributed from North Carolina to the Gulf of St. Lawrence, and on occasion as far north as Labrador (Bigelow and Schroeder 2002). Mackerel are a fast moving, schooling species that undergo extensive seasonal migrations. The northern and southern components generally over-winter on the continental shelf off the Mid-Atlantic bight and begin their spring migration in April. The southern component spawns along the Southern New England corridor and disperses throughout the Gulf of Maine-Georges Bank region during summer (Sette 1950; Morse et al. 1987; O'Brien et al. 1993). It is believed that the northern component crosses Georges Bank during April-May reaches the Scotian shelf in late May or early June and moves into the Gulf of St Lawrence during late June and early July to spawn in the Magdalen shallows region (Sette 1950; Gregoire et al. 2003; DFO 2004; Gregoire 2005). Post spawning fish disperse into the Gulf as far east as Newfoundland. This schooling species often attains ages greater than 10; ages up to 14 are not uncommon. Mackerel begin to mature at age 2, and are generally fully mature at age 3 (Bigelow and Schroeder 2002; Gregoire et al. 2003). They exhibit a planktivorous diet, feeding mainly on zooplankton, chaetognaths, euphasids; and larval fish (Bigelow and Schroeder 2002). Mackerel are preyed upon by a large number of medium-sized predatory fishes such as cod, white hake, and spiny dogfish; marine mammals such as pilot whales, white-sided dolphins, and common dolphins; seabirds such as greater shearwaters and northern gannets; and large pelagic fish such as swordfish and blue shark, throughout their range.

The Mid Atlantic Fishery Management Council manages mackerel as part of the Atlantic mackerel, Squid, and Butterfish (MSB) Fishery Management Plan. The current overfishing definition is based on an MSY of 326,000 mt, a Bmsy of 890,000 mt, and a limit fishing rate of Fmsy = 0.45 (MAFMC 1998; NEFMC 1998). Overfishing for this species is defined as occurring when Fmsy is exceeded, and the overfishing limit is Fmsy = 0.45 when the SSB is greater than 890,000 mt. An MSY of 326,000 mt represents the current estimate of long-term potential catch for the stock and was revised in Amendment 8 of the FMP. The F target is defined as the tenth percentile of Fmsy and is set at F=0.25. If SSB is less than 890,000, F target decreases linearly from 0.25 at 890,000 mt to zero at 450,000 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 the mackerel OFD.

The most recent assessment for this stock was completed in 1999 (SARC 30) (NEFSC 2000). Although no quantitative assessment was accepted, conclusions were that the stock was at a high level of biomass, F was low, and that catches were well below the MSY of 326,000 mt.

2.0 THE FISHERY

Commercial Landings

Commercial mackerel landings by the United States averaged 2,368 mt from 1960-1983, peaked at 31,261 mt in 1990, and declined to 4,666 mt in 1993 (Table B1; Figure B1). USA landings increased to 16,137 mt in 1996, declined to 5,646 mt in 2000 and steadily increased to 53,724 mt in 2004. Recreational landings in the USA have generally declined during 1979-2004. Landings averaged 2,945 mt during 1979-1988 and declined to a low of 344 mt in 1992 (Table B1: Figure B1). Landings in the US sport fishery peaked at 1,735 mt in 1997, declining slightly thereafter, but remaining relatively steady until declining to 724 mt in 2003 and 467 mt in 2004. Landings by Canada averaged 6,891 mt during 1960-1967, and 23,882 during 1968-2000 (Table B1; Figure B1). Canadian landings increased steadily from 23,868 mt in 2001 to 51,444 mt in 2004. For details of Canadian landings see Gregoire et al. (2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas. Landings by foreign countries, primarily during the ICNAF era, averaged 143,532 mt during 1961-1977, and 18,315 mt during 1978-1991 (Table B1; Figure B1). Foreign countries were excluded from fishing in the US EEZ after 1991.

Sampling Intensity

Commercial length frequencies used to characterize USA landings were obtained from port samples obtained in the Northeast Region. The mackerel fishery is strongly seasonal, with most of the landings occurring during the first 5 months of the calendar year and any remaining landings during November and December. Because of stable growth patterns, length samples were aggregated over the first and second half of each year. Most of the landings occurred during the first half of the year in all years from 1998-2004, but in some landings occurred in the second half of the year during 2001-2004 (Table B2). Sample size for commercial length compositions ranged from 907 in 2000 to 4,297 in 1999 for the first half of each year (Table B2). Sample size for length data for the commercial fishery in the second half of 2001-2004 ranged from 116 in 2001 to 322 in 2003. Landings at age for the second half of 2001-2004 were estimated with length data from the 4th quarters of each year (Table B2). A length-weight relationship was used to estimate sample weight and expansion factors for commercial samples from 1998-2004. Length-weight parameters used in the last assessment (a=0.0059, b=3.154) were used for the estimation of commercial catch at length.

Recreational length samples obtained from the MRFSS data base were used to characterize the landings of this species by sport fisherman. Sample numbers and lengths were judged to be adequate enough to estimate recreational catch at length. Recreational length samples were available for each year during 1998-2004 and ranged from 483-1,347 fish measured (Table B2). The same length-weight equation was used to estimate sample parameters and expansion factors for the recreational landings data.

Age length data used for estimating commercial and recreational catch at age were obtained from commercial port samples, sea sampling, and NEFSC Spring and Winter bottom trawl surveys. Combined age-length keys from these sources were used to age commercial and recreational landings from the first half of 1998-2004 (Table B2). . Sample size for the first part of the year during 1998-2004 ranged from 719-1901 (Table B2). Generally only fall survey ages in small numbers were available to age the second half of each year during 2001-2004, samples sizes ranged from 71-121. Catch-at-age for Canada was developed using similar procedures, although many more length samples were available. For details of Canadian commercial length and age sampling see Gregoire et al. (2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas.

Catch-at-Age

USA commercial and recreational catch at age for 1962-1997 were taken from the previous assessment (NEFSC 2000). Catch at age for the USA during 1998-2004 were estimated from the length and age composition and landings data previously cited (Table B3). Canadian catch at age data for 1998-2004 were obtained from DFO Canada (Gregoire et al. 2003) and are included in Table (B3). Canadian catch-at-age data for 1990-1993 were updated based on a revision in Canadian landings for 1990-1993. For details of Canadian catch-at-age see Gregoire et al. 2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas.

Commercial Mean Weights

Commercial mean weights used in the current assessment were obtained from the previous assessment for 1962-1997 and were estimated for 1998-2004. The length weight relationship used to estimate sample weights (a=0.0059, b=3.154) was used to calculate the mean weights at age for the USA commercial fishery for 1998-2004. Mean weights for the commercial fishery during 1998-2004 were calculated as weighted means of the USA and Canadian fishery catch-at-age and mean weights-at-age (Table B4).

3.0 RESEARCH SURVEY ABUNDANCE INDICES FOR TREND

Research survey abundance indices are available from winter and spring NEFSC bottom trawl surveys for assessing the status of the mackerel resource. Survey indices are available from NMFS surveys for the winter 1992-2005 and spring 1968-2005. The autumn survey series from 1963-2004 was investigated for use as a tuning index, but very few mackerel are taken in this survey and an unknown proportion, perhaps large, is distributed in Canadian waters, and is unavailable to the USA survey.

Standard and ln transformed spring survey indices were updated for 1998-2005. Standard indices in weight and number per tow continued to show improving trends for the stock during 1989-2005 (Table B5; Figure B2). The biomass index generally increased from 1989-1996, declined slightly in 1997-1998, and increased from 1999-2004. Mean number per tow indices followed nearly the same trends, increasing over the early 1990s, decreasing in 1997-1998, and increasing again from 1999-2004. The index reached 116 in 2001, the highest value in the 43 year series (Table B5; Figure B2).

Spring indices for 1998-2004 were recomputed to produce aggregated ln retransformed catch per tow indices. The standard number per tow index increased by an order of magnitude from the 1980s to the 1990s and increased further from 1998-2004. The index was high and relatively stable throughout the 1990s, except for 1997 and increased in 2000 and 2001 (Table B5; Figure B4). The highest value in the series was obtained in 2001 (59.106). Number per tow indices at age (ln retransformed) were updated for 1998-2005. Indices at age were generally higher, with a few exceptions, for ages 1-6 during 1997-2004 than for all other years in the 1968-2005 time-series (Table B6).

The winter bottom trawl survey began in 1992 and was included as an index for this stock in the previous assessment. The standard biomass and abundance indices for mackerel are generally high, but variable (Table B7). The biomass index ranged from 0.25-32.05 kg/tow during 1992-2005 (Table B7; Figure B4). Number per tow ranged from 1.16 to 245.58 during this same period. Some of the variation in survey indices may be attributed to the more inconsistent coverage of survey strata during the winter survey. Number per tow at age indices (ln retransformed) were produced for the winter survey, including ages 1-10+ (Table B8). Indices in this survey have also increased in recent years (Table B8).

Growth

Trends in average weight from the spring survey were examined to see if there were any changes during 1968-2005. With the exception of the period after the ICNAF fishery in the 1970s, average weights have fluctuated between 100-200 grams, but there appears to be a slight overall decline from 1985 onward (Figure B6). Average weight-at-age from the USA and Canadian fishery were also examined for trends (Figure B7). The same increase in weight occurred following the ICNAF era, but mean weights have been relatively constant since then and very similar to weights in the 1960s through the mid-1970s (Figure B7).

Predation Mortality

Evidence suggests that natural mortality rates for this species may be more variable than the current constant value (M=0.2) used in assessments. Overholtz et al. (2000) studied consumption of pelagic fishes and squids in the Northeast shelf ecosystem and found that the pelagic fish community in the region is heavily consumed by predatory fishes in the region. This study suggested that mackerel were important in the diets of predatory fish in the region during 1973-1997. Consumption by predatory fish as a group was certainly important during this time (Figure B8). Spiny dogfish are an important consumer of mackerel, removing significant quantities of this prey species during 1979-1997 (Figure B9).

Mackerel Distribution

The positions of mackerel survey catches during 2002-2005 from the NEFSC spring survey were plotted to observe if any changes in distribution had taken place over that time period. Mackerel were widely distributed over the Mid-Atlantic-Georges Bank region during 2002 (Figure B10). During 2003, mackerel were further to the south and distributed about midway along the Mid-Atlantic continental shelf (Figure B11). In 2004, the mackerel distribution was further to the south and further offshore than in 2003 (Figure B12). Mackerel survey catches were much further to the south and more offshore in 2005 than during the three previous years (Figure B13).

4.0 VPA CALIBRATION AND DIAGNOSTICS

Catch-at-age and mean weight data for 1962-2004 and bottom trawl survey data for winter 1992-2004 and spring 1968-2004 (ages 1-10+), were used in a VPA calibration to update the previous assessment (NEFSC 2000). Results from this run suggest that current spawning stock biomass is rebuilding, but much below levels observed in the early 1970s (Figure 1 App1). Fishing mortality increased steadily from 1980 through 2002, reaching very high values of 0.7 in 1999 and over 1.0 in 2002 (Figure 2 App1). Trends in the observed vs./ predicted series for the spring survey show patterning with a block of negative residuals prior to 1984 and positive residuals thereafter (Figure 3 App1). Observed-predicted trends from the winter survey are mixed, but the fit is reasonable (Figure 4 App1). Since there was a prominent retrospective pattern in the previous assessment, a new analysis was completed. There is still a prominent retrospective pattern for spawning stock biomass in the current VPA with successive years from 2002-2004 showing major declines in SSB when compared to the previous year (Figure 5 App1). Fishing mortality also had a pattern indicating that F was underestimated during 2002-2004 (Figure 6 App1).

Since the retransformed winter trawl series in relatively flat (Figure B5) and residual patterns for the spring survey from the previous run were poor, the next VPA run utilized only the spring survey time-series. The spring series is the longest time-series available and has long been considered the best available index for monitoring trends in this stock. Scaling was a problem with this model run, spawning stock biomass increased to very high values, exceeding 40 million mt during 2000-2004 (Figure 7 App1). The pattern in fishing mortality was much different than in the first run, with higher mortality rates in the 1970s and much lower F's from the 1980s onward (Figure 8 App1). Model fit improved greatly in this model formulation (Figure 9 App1). However, because of the many problems encountered in the VPA formulations, another more flexible modeling approach (ASAP), that can be used to address issues such as fishery selectivity, biomass scaling, and recruitment estimation, was utilized.

5.0 ASAP FORWARD PROJECTION DESCRIPTION

ASAP is an age structured forward projection model with flexibility to address fishery selectivity, stock-recruitment, and constraints on virgin biomass, steepness, scale and other factors. The analysis for Atlantic mackerel starts in 1962 and projects forward through 2004. Total biomass, spawning stock biomass, recruitment, fishing mortality, and surplus production are estimated in the model.

Growth

The same mean weight data from the VPA (1962-2004 ages 1-10+) were used in ASAP model runs.

Maturity

Maturity was assumed to be 0.2 at age 2 and 1.0 at age 3 and older for mackerel.

Natural Mortality

Natural mortality was assumed to be 0.2 as in previous assessments.

Partial Recruitment

Partial recruitment was assumed to be 0.2 at age 1, 0.6 at age 2 and 1.0 for age 3 and older. These data were based on the old VPA run (NEFSC 2000), the new VPA run and results in the recent USA fishery.

Recruitment

A Beverton-Holt stock-recruitment model was used to model recruitment with the alpha and beta parameters estimated internally in the model. In ASAP runs 1 and 2 the SR relationship was assumed to be fit without any error, while in run 3 and the base case run the relationship was fit with error (lamda=1).

Surplus Production

Surplus production for the mackerel stock was estimated by using parameters from the B-H model fit. Stock recruitment parameters were estimated internally and used to calculate management parameters such as MSY and Fmsy. In addition output from the model was used to a fit a Fox model (Fox 1975) and a Schaefer model (Schaefer 1954).

Landings

The total catch-at-age for the USA and Canada model were included in the ASAP formulations (Figure B3). For details of Canadian CAA see Gregoire et al. (2003), DFO (2004), and Gregoire (2005) available online at www.dfo-mpo.gc.ca/csas.

Research Surveys for Trend

The spring survey (1968-2004 ages 1-10+, and 1-7+) was used to tune the mackerel ASAP model.

6.0 ASAP INITIAL MODEL TRIALS AND RESULTS

A series of ASAP model runs were conducted to address various aspects of model scale and goodness of fit. The first model run repeated the last formulation used in the VPA, a run that utilized only the spring survey. Results from this trial showed an improvement in scale for spawning stock biomass when compared to the VPA (Figure 10 App1). The historic period during 1962-1977 was very similar in magnitude to the VPA, but the spawning stock increased steadily thereafter to over 6.5 million mt in 2003 (Figure 10 App1). The pattern in fishing mortality showed a large increase in the mid 1970s followed by very low rates thereafter (Figure 11 App1). However, a comparison of the observed vs. predicted survey series indicated that this model run produced estimated values that were functionally a smoothed series through the survey index values (Figure 12 App1). This occurred because the SR relationship was fit without error, resulting in a smooth trend in predicted survey values. Overall, this model run resulted in a large improvement in scaling when compared to the similar VPA run, but diagnostics (residuals) were very poor. To further address issues of scale and poor model fit, another ASAP model run was completed.

It is hypothesised that another important issue related to the spring time series is a change in catchability due to a conversion to polyvalent doors that occurred in 1985. After 1984, survey catches of mackerel on average increased dramatically when compared to values prior to the door change (Table B5; Figure B2). The GARM and trawl warp investigation in 2002 suggested that the current door configuration for the 36-Yankee trawl results in an overspread condition for the net (S. Murawski, pers. comm.. 2002). This means that now the net is always open both high and wide. Evidence suggests that historically the 36-Yankee survey gear probably did not operate in this fashion because water hauls were common and the net probably functioned in a more compressed state (Pers. Comm. NEFSC Survey Group, *various years)*. Results from door comparison work that was completed on a variety of species, were not available for mackerel, because the design was oriented toward groundfish and few mackerel were available during the experiment (Byrne and Forrester 1991). Coefficients for Atlantic herring from this same gear study were not significant, but these experiments were not designed to estimate the effects of door changes on herring. Extensive work on herring in subsequent studies confirmed that the door change was an important factor in explaining survey catchability changes in the spring survey for this species (Overholtz et al. 2004). Therefore, the spring survey was split in 1985 to address the survey catchability issue for mackerel. The two separate series were used to tune the mackerel ASAP model in this model run.

Results from the ASAP model utilizing the split spring time-series showed an improvement in scale, but a continued smoothing of survey predicted values. Again, the smoothing resulted from the assumption of no error in the SR relationship. Spawning stock biomass increased steadily from the late 1970s to 4 million mt in 2003 (Figure 13 App1). Fishing mortality was high in the 1970s, increased in the late 1980s and early 1990s, and slightly increased in recent years (Figure 14 App1). Patterns in the observed vs. predicted spring survey series were apparent in the pre-1985 and post 1985 periods, as the ASAP model smoothed the predicted values (Figure 15; 16 App1).

As a further approach for addressing the problem of scale and patterns in residuals, some of the features of the ASAP model that are useful for addressing issues of scale directly were used. A stock-recruitment function (Beverton-Holt) was fit with a low emphasis coefficient (lambda = 1) to attempt to improve these factors. Results suggest that biomass decreased substantially and the pattern in the residuals improved greatly. Spawning biomass in the 1970s peaked at over 1.5 million mt, declined, and then increased steadily from the late 1970s onward to a maximum of 2.7 million mt in 2003 (Figure 17 App1). Fishing mortality increased slightly in the 1970s over previous runs, but remained relatively low from 1980-2004 (Figure 18 App1). Patterns in the survey residuals improved greatly, with observed and predicted series tracking nicely for both the pre 1985 and post 1985 series, and with little patterning in both series (Figures 19; 20 App1). Results for the various likelihood components in the trial, base case, and sensitivity runs are presented in Table (B11).

7.0 BASE CASE MODEL

The base case model for mackerel used a CAA that was further aggregated to 7+. The recent lack of older aged fish in the spring survey (Table B6) is probably related to availability of these larger faster swimming fish to the survey gear. The Yankee-36 trawl has always had a tendency to under-sample large mackerel over the years, but for some unknown reason survey catches in the most recent years have been low or zero (Table B6). One explanation is that large mackerel have moved further offshore or south during recent cold winters. The average temperature in the spring survey during 2002-2004 was much below the average from the preceding decade (Figure B14). The commercial fishery in recent years has also caught few larger fish, but this may be explainable since the fishery has been narrowly focused in inshore areas off Rhode Island and New Jersey and apparently large fish have not been available in those areas (Figure B15). Commercial vessels have done little searching in offshore areas that are far removed from inshore fishing grounds that are close to ports. Therefore, to further address issues of scale and goodness-of-fit caused by low survey and commercial landings of older fish, the CAA was aggregated at 7+. Preliminary model runs with a delay-difference biomass model (Schnute 1985) (biomass, age 2 and 3+) also indicated that aggregating over older age groups might be a useful approach. Emphasis coefficients for the base case model are listed in Table (B9). The working group decided that this was the best model formulation currently available for determining the status of the mackerel stock. Several additional sensitivity runs were examined by the WG and results are presented in subsequent pages. Results for the accepted base case run are as follows.

Total Biomass

Total biomass reached 1.9 million mt in 1969 and declined to just over 0.7 million mt in 1977 (Figure B16). Total biomass increased steadily to 1.4 million mt in 1999 and then increased rapidly to 2.9 million mt in 2004 (Figure B16). Total biomass ranged between 2.3 and 2.9 million mt during 2000-2004, averaging 2.5 million mt.

Spawning Biomass

Spawning biomass peaked in 1972 at 1.7 million mt, declined until 1976, and began to increase thereafter (Figure B17). During 1978-2000 spawning biomass increased steadily to 1.3 million mt in 2000. SSB continued to increase and then stabilized at 2.3 million mt in 2003-2004 (Figure B17). Spawning biomass ranged between 1.3 and 2.3 million mt in 2000-2004 and averaged 2.0 million mt.

Fishing Mortality

Fishing mortality was relatively high during 1969-1975, peaking at 0.54 in 1975 (Figure B18). Fishing rates dropped dramatically to a low of 0.05 in 1978 followed by a very low and stable period during 1979-1986. Fishing mortality reached a small peak in 1988 of 0.09, coincident with the joint venture (JV) fishery that operated for several years, and then declined to a low of 0.02 in 2000 (Figure B18). The average fishing rate during 2001-2004 was 0.04 and F in 2004 was 0.05.

Stock-Recruitment, Recruitment

Recruitment has been highly variable for the mackerel stock over a range of spawning biomass between about 0.3-2.3 million mt (Figure B19). Recruitment ranged between 0.1-5.8 billion fish during 1962-2004 and averaged 1.1 billion fish (Figure B20). There have been three large year classes during that period, the 1967, 1982, and 1999 year-classes (Figure B20). Recruitment from the 2002 and 2003 year-class appears promising, but is difficult to quantify at this time. The recent average recruitment during 2001-2004 was 1.6 billion fish and recruitment in 2004 was estimated at 2.8 billion.

Surplus Production

Biological reference points were estimated with a Fox model (Fox 1975), Schaefer model (Schaefer 1954) and from an internal B-H stock-recruitment relationship. Reference points from the B-H parameters were MSY = 89,000 t, SSBmsy = 644,000 t, and Fmsy = 0.16. Surplus production (SP) in the mackerel stock was available sporadically during the 1962-2004 time-period (Figure B21). Periods of SP occurred before the ICNAF fishery in the late 1960s, during the early 1980s, and more recently in the late 1990s through 2003 (Figure B21). Results from the Schaefer and Fox models were not used because the surplus production (SP) data surfaces for both model was flat over a wide range of SSB, resulting in very high estimates of K and Bmsy. Only the results from the B-H model were deemed to be useful by the committee. The average SP for this stock during 1962-2003 was 148,000 mt; this value can serve as a proxy upper bound on MSY for the current assessment.

Precision of ASAP Estimates

The relative precision of the estimates for spawning stock biomass and fishing mortality were calculated using the Hessian matrix from the ASAP model fitting procedure. This approach produces a mean and standard deviation for every parameter in the model (Table B12). Results indicate that estimates for both SSB and F are moderately precise. The estimated mean SSB was 2.32 million mt, ranging from 1.49-3.14 million mt, for a two standard deviation interval. The average estimate of F was 0.05, ranging from 0.035-0.063, again for a 2 SD interval. Results from an MCMC run of the ASAP model indicated that these 2SD intervals are comparable to a 95% CI.

Model Diagnostics

Plots of observed-predicted series for the spring NEFSC survey used to tune the ASAP model for trend were produced as a diagnostic measure of goodness of fit. Plots of observed vs. predicted data series (log scale) are shown in Figures (B22; B23) for the base case model. Survey observed and predicted series for the pre 1985 and post 1985 period track nicely with few indications of patterning. The committee examined all the available ASAP diagnostics such as age and year specific observed vs. predicted CAA, indices at age, effective sample size, stock-recruitment plot, and population by year, and concluded that these were also reasonable.

Retrospective Analysis

A retrospective analysis was conducted to observe if there are any patterned trends in SSB and recruitment of the ASAP base model. Results for SSB indicate a moderate pattern for 2001-2003 and larger difference for 2004 (Figure B24). There also appeared to be a change in trend for 2004. For recruitment there appears to be some consistent patterning for years prior to 1999. For the large 1999 year-class the pattern is not consistent among years, but estimates are highly variable across years (2000-2004) (Figure B25).

Projections

Natural mortality was set at M=0.2 for the projections. Partial recruitment to the fishery was set at 0.2 for age 1, 0.6 for age 2, and 1.0 for age 3 and older. Maturity was held constant a 0.2 at age 2 and 1.0 at age 3 and older. Mean weights used in the projections were held constant, the values used were for 2004 (Table B4).

Deterministic projections for 2006-2008 were conducted by inputting an estimated catch of 95,000 mt (209 million lbs) in 2005, a target fishing mortality of 0.12 (MAFMC 1998, Ftarget=0.75 x Fmsy) in 2006-2008, and annual recruitment values based on the S/R curve that was estimated from data. If 95,000 mt (209 million lbs) are landed in 2005, SSB in 2006 will increase to 2,640,210 mt (5.8 billion lbs) (Table B13). If the Ftarget F=0.12 is attained in 2006-2008, SSB will decline to 2,304,020 mt (5.1 billion lbs) in 2007 and to 2,043,440 mt (4.5 billion lbs) in 2008. Landings during 2006-2008 would be 273,290 mt (603 million lbs), 238,790 mt (527 million lbs), and 211,990 mt (467 million lbs), respectively (Table B13). These landings are the result of an unusually large year-class (1999) present in 2005, and will not be sustainable in the long term. It is expected that these projected landings will decline to MSY (89,000 mt (196 million lbs)) levels in the future when a more average recruitment condition exists in the stock.

8.0 SENSITIVITY ANALYSIS

An additional trial run was conducted to address the retrospective problem that occurred in the base run. It was assumed that there is still a great deal of variability in the model fit caused by the lack of older fish in the CAA and survey. Even aggregating the CAA and survey to 7+ did not appear to alleviate this problem fully. We therefore decided to allow the model to estimate selectivity during 1995-2004 in the fishery to see if this impacted the results. Emphasis coefficients for this model are listed in Table (B10). This approach changed and improved the retrospective pattern in SSB and recruitment. The retrospective for SSB appears to have been minimized as all the trajectories are consistent and there is no apparent pattern (Figure 1 App2). The retrospective pattern for recruitment also appears to be lessoned, but there is still some sequential patterning for year-classes prior to 1999 and a clear pattern for the 1999 year-class (Figure 2 App2).

The working group also wanted to see an ASAP model run that included the NEFSC winter bottom trawl survey to compare the results to the VPA. SSB in this model run showed the familiar peak in biomass in the early 1970s, but this was followed by a steep decline in SSB to a low of 99,000 mt in 2004 Figure 3 App2). This steep decline in SSB was the result of a very sharp increase in fishing mortality during the late 1990s and 2000-2004 (Figure 4 App2). The observed vs. predicted series for the winter (Figure 5 App2), and spring 1 (Figure 6 App2) were reasonable, but the pattern for the spring2 series deteriorated, with a series of negative residuals from 1990-2003 (Figure 7 App2). Adding the winter series to the ASAP model obviously caused the model fit to deteriorate seriously, producing infeasible trends in SSB and fishing mortality.

The final sensitivity run requested by the committee was a model that allowed selectivity to be estimated for the entire time-series from 1962-2004. This run was accomplished by using the same parameter setup as for the base case, but designating two separate time-blocks, one from 1962-1994 and the other from 1995-2004, and letting the model estimate fishery selectivity. In this run, SSB increased to over 1.6 million mt in 1972, declined sharply, and then steadily increased to about 1.4 million mt in 2004 (Figure 8 App2). As in several of the previous runs, fishing mortality peaked in the 1970s, declined, and remained low during the 1980s-2004. However, in this run F was much more asymptotic during the early years and then more dome shaped during the late 1990s, through 2004 (Figure 9 App2). The observed vs. predicted series for this model show that goodness of fit was reasonable with both the spring1 and spring2 series showing little patterning (Figure 10; 11 App2). The fishery selectivity for this model was asymptotic for the early years of the time-series and showed a moderate dome thereafter (Figure 12 App2).

9.0 SARC-30 RESEARCH RECOMMENDATIONS (TOR 6)

a. Explore logbook data for information on catch rates and geographic distribution.

No analysis was completed on this recommendation. Previous analyses have suggested that catch rates from the mackerel are an unreliable index of abundance because electronics are used to actively search for this species. Frequent technological improvements in winches, nets, doors, and other equipment also make it very difficult to compare fishery dependent catch rates among years. The fishery also tends to be aggregated in isolated small areas, piggybacked on the success of other vessels during the season. The recent and current fishery in the USA takes place along the inshore areas of New Jersey and Rhode Island depending on the location of mackerel on the continental shelf during winter. This factor means that very little information on the distribution of mackerel can probably be obtained from fishery dependent data.

b. Explore Canadian trawl survey indices for use in VPA calibrations.

Several additional trawl survey indices and egg indices were explored as tuning indices, but currently they do not appear useful in resolving assessment issues with this stock (Pers. comm. F. Gregoire DFO 2005)

c. Explore the feasibility of acoustic surveys for monitoring stock size.

Several attempts have been made to use acoustics to survey mackerel during recent winter cruises on the RV Delaware II. To date there has been little success, but this does not preclude the use of acoustics on this species, especially with the RV Bigelow in future.

d. Examine estimates of Z calculated from research vessel survey data with respect to their usefulness in estimating natural mortality.

No progress was made on this recommendation during the interim period.

10.0 RESEARCH RECOMMENDATIONS

- Currently there are historical age data that are only in hard copy form. These data should be put into an electronic database to allow examination of alternative methods, such as non-transformed indices.

- The current approach of transforming the survey indices should be expanded to include an exploratory analysis of geometric mean or other distributions instead of retransformed mean.

- Examine NEFSC Spring survey since 1999 to see what may have caused large increases in catch/tow.

- Explore use of environmental covariates to help explain recruitment deviations from the stock recruitment relationship.

- Consider the use of environmental variables to adjust the NEFSC Winter and Canadian surveys for changes in availability and consider their use as tuning indices in modeling.

- Increase sampling of commercial landings and survey catches to better characterize age and length composition.

- Conduct simulation exercises to determine the sample sizes required to detect old fish with high probability in commercial samples assuming they are present.

- Explore discard estimation, especially for years when large year classes are first entering the fishery.

- Pilot survey to explore for old fish to test hypothesis regarding dome in commercial fishery selectivity.

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MACKEREL TABLES.

Table B1. Commercial and Recreational landings (mt) of Atlantic mackerel for the USA, Canada, and other countries from NAFO SA 2-6 during 1960-2004

1 Landings by Canadian vessels (Commercial) or foreign countries (Foreign) in Canadian waters (SA 2-4)

2 Landings by USA vessels (Commercial), recreational sources (Recreational), or foreign countries (Foreign) in USA waters (SA5-6).

	Canada		**USA**			
Year	**Commercial[1]**	**Foreign[1]**	**Commercial[2]**	**Recreational[2]**	**Foreign[2]**	**Total**
1960	5888	0	1396	2478	0	9762
1961	5458	11	1361	-	11	6841
1962	6901	64	938	-	175	8078
1963	6363	99	1320	-	1299	9081
1964	10786	174	1644	-	801	13405
1965	11185	405	1998	4292	2945	20825
1966	11577	1244	2724	-	7951	23496
1967	11181	62	3891	-	19047	34181
1968	11134	9720	3929	-	65747	90530
1969	13257	5379	4364	-	114189	137189
1970	15710	5296	4049	16039	210864	251958
1971	14942	9554	2406	-	355892	382794
1972	16254	6107	2006	-	391464	415831
1973	21619	16984	1336	-	396759	436698
1974	16701	27954	1042	-	321837	367534
1975	13544	22718	1974	5190	271719	315145
1976	15746	17319	2712	-	223275	259052
1977	20362	2913	1377	-	56067	80719
1978	25429	470	1605	-	841	28345
1979	30244	368	1990	3588	440	36630
1980	22136	161	2683	2364	566	27910
1981	19294	61	2941	3233	5361	30890
1982	16380	3	3330	666	6647	27026
1983	19797	9	3805	3022	5955	32588
1984	17320	913	5954	2457	15045	41689
1985	29855	1051	6632	2986	32409	72933
1986	30325	772	9637	3856	26507	71097
1987	27488	71	12310	4025	36564	80458
1988	24060	956	12309	3251	42858	83434
1989	20795	347	14556	1862	36823	74383
1990	19190	3854	31261	1908	30678	86891
1991	24914	1281	26961	2439	15714	71309
1992	24307	2417	11775	344	0	38843
1993	26158	591	4666	540	0	31955
1994	20564	49	8877	1705	0	31195
1995	17650	0	8479	1249	0	27378
1996	20364	0	16137	1416	0	37917
1997	21309	0	15400	1735	0	38444
1998	19334	0	14415	670	0	34419
1999	16561	0	12026	1335	0	29922
2000	13383	0	5646	1448	0	20477
2001	23868	0	12336	1538	0	37742
2002	34402	0	26452	1286	0	62140
2003	44475	0	34292	724	0	79491
2004	51444	0	53724	467	0	105635
2005	0	0	41234	0	0	41234

Table B2. USA sampling of Atlantic mackerel commercial and recreational landings during 1998-2004.

	Commercial Lengths		Ages-All Sources		Recreational Lengths
Year	**Jan-June**	**July-Dec**	**Jan-June**	**July-Dec**	
1998	1956		1901		615
1999	4297		920		979
2000	907		625		723
2001	2910	116	1333	91	778
2002	2264	197	1207	118	483
2003	2465	322	1061	121	606
2004	938	163	719	71	1347

Table B3. Atlantic mackerel catch-at-age (millions) for NAFO SA 2-6 during 1962-2004

Year	1	2	3	4	5	6	7	8	9	10+	Total
1962	16.1	2.8	15.2	3.8	1.2	1.6	1.4	0.8	0.4	0.4	43.7
1963	1.1	4.2	1.3	26.3	6.0	0.3	0.2	0.2	0.2	0.2	40.0
1964	12.9	7.0	4.1	4.0	19.4	4.1	3.9	0.7	0.8	0.2	57.1
1965	9.0	3.6	2.9	4.0	5.2	19.5	4.2	4.0	0.7	0.0	53.1
1966	24.0	11.5	5.3	2.6	4.7	7.9	21.8	0.5	0.2	0.0	78.5
1967	0.8	26.7	19.8	3.5	3.3	5.1	6.1	32.3	0.3	0.0	97.9
1968	141.4	61.5	59.3	38.1	14.3	6.6	0.7	1.0	6.1	0.1	329.1
1969	7.1	262.1	160.7	65.8	5.7	3.0	2.0	3.1	2.2	8.3	520.0
1970	193.5	54.5	522.1	162.9	27.6	7.0	5.3	9.9	10.0	6.6	999.4
1971	74.6	294.2	127.4	558.9	203.5	34.6	8.9	3.6	4.3	15.3	1325.3
1972	22.1	85.7	256.2	182.6	390.4	87.3	24.0	4.2	8.2	9.4	1070.1
1973	161.8	283.2	285.1	233.6	192.4	197.2	31.2	11.0	4.1	5.4	1405.0
1974	95.9	242.2	264.4	101.5	114.3	111.8	108.3	25.7	6.4	3.3	1073.8
1975	373.7	431.4	113.7	100.8	58.6	67.8	51.9	50.5	12.5	3.3	1264.2
1976	12.5	353.5	272.5	85.7	52.4	27.3	40.5	34.6	22.6	14.8	916.4
1977	2.0	27.0	101.0	54.0	12.0	9.9	5.6	6.3	3.8	4.2	225.8
1978	0.1	0.2	4.7	17.4	13.3	8.4	4.7	2.2	4.5	7.3	62.8
1979	0.4	0.6	1.3	7.1	18.6	13.1	6.2	2.6	2.2	6.5	58.6
1980	1.2	10.9	1.0	1.0	6.9	13.8	4.7	2.0	1.0	5.2	47.7
1981	16.1	7.1	9.2	1.4	2.0	6.1	11.7	4.9	2.5	3.5	64.5
1982	3.7	11.8	2.7	9.1	1.2	1.9	3.4	8.4	2.9	5.1	50.2
1983	2.2	15.3	6.5	1.9	7.0	0.7	1.2	5.5	10.2	6.5	57.0
1984	0.5	40.4	27.2	3.2	1.2	4.6	0.6	0.7	3.4	14.0	95.8
1985	3.4	1.9	135.7	33.4	2.7	0.8	3.2	0.3	0.5	11.4	193.3
1986	1.1	10.4	6.5	91.7	22.1	1.7	0.5	3.1	0.2	5.6	142.9
1987	9.7	14.2	13.3	7.5	106.9	17.5	2.6	0.4	2.1	3.8	178.0
1988	1.5	13.0	10.3	10.1	11.5	107.4	22.5	2.6	1.2	5.7	185.8
1989	1.9	14.0	11.0	7.4	6.8	2.3	85.7	4.3	0.8	1.7	135.9
1990	1.7	19.9	30.4	7.9	6.4	4.3	0.8	54.1	2.6	1.2	129.4
1991	1.4	12.6	55.2	23.9	6.1	3.9	3.3	1.0	27.3	1.2	136.0
1992	0.7	6.5	5.0	24.9	14.9	2.0	1.4	1.2	1.3	16.1	74.0
1993	1.1	8.8	10.9	6.1	16.4	8.9	1.9	0.8	1.1	8.4	64.5
1994	1.9	1.6	12.0	13.8	5.3	19.4	6.7	1.1	0.3	4.0	66.1
1995	11.9	20.7	2.7	9.5	8.2	3.2	10.3	3.2	0.3	0.9	71.0
1996	3.0	26.5	24.1	1.9	12.6	9.8	2.5	10.2	2.3	1.5	94.5
1997	6.9	22.0	23.4	11.1	1.1	8.5	6.8	2.8	7.2	1.9	91.6
1998	2.2	29.8	19.1	16.6	8.7	1.2	5.9	4.1	1.0	2.4	91.0
1999	1.7	6.5	23.3	14.1	9.2	4.8	1.4	2.9	2.0	1.3	67.2
2000	26.0	9.3	6.0	10.3	4.4	3.3	0.7	0.1	0.2	0.4	60.6
2001	8.6	74.9	23.3	7.3	9.6	2.3	2.1	0.7	0.2	0.3	129.4
2002	9.9	12.4	120.0	14.2	5.3	9.7	3.1	0.8	0.2	0.1	175.7
2003	9.6	23.5	26.4	121.8	14.0	5.0	4.9	0.3	0.0	0.0	205.5
2004	35.1	74.0	22.0	24.9	120.1	9.0	2.8	0.9	0.2	0.0	288.8

Table B4. Mean weight-at-age (USA and Canada, kg) for Atlantic mackerel during 1962-2004.

Year	1	2	3	4	5	6	7	8	9	10+
1962	0.130	0.208	0.289	0.365	0.433	0.491	0.541	0.581	0.614	0.657
1963	0.120	0.192	0.264	0.334	0.395	0.448	0.492	0.529	0.559	0.593
1964	0.116	0.188	0.262	0.332	0.395	0.450	0.495	0.533	0.564	0.588
1965	0.123	0.200	0.278	0.352	0.419	0.477	0.525	0.565	0.598	0.595
1966	0.128	0.209	0.294	0.374	0.447	0.509	0.562	0.605	0.641	0.595
1967	0.123	0.202	0.283	0.360	0.428	0.489	0.540	0.581	0.615	0.595
1968	0.148	0.241	0.335	0.425	0.506	0.576	0.634	0.683	0.722	0.753
1969	0.131	0.214	0.300	0.382	0.456	0.520	0.574	0.618	0.654	0.683
1970	0.107	0.179	0.253	0.324	0.389	0.444	0.491	0.530	0.562	0.596
1971	0.110	0.181	0.256	0.327	0.391	0.446	0.494	0.532	0.564	0.599
1972	0.123	0.210	0.300	0.386	0.464	0.533	0.590	0.638	0.677	0.723
1973	0.113	0.189	0.269	0.345	0.414	0.473	0.524	0.565	0.600	0.635
1974	0.111	0.190	0.273	0.352	0.425	0.487	0.541	0.585	0.621	0.655
1975	0.104	0.176	0.252	0.326	0.393	0.451	0.500	0.540	0.573	0.606
1976	0.097	0.168	0.244	0.316	0.382	0.440	0.489	0.530	0.563	0.592
1977	0.114	0.198	0.288	0.375	0.454	0.524	0.582	0.631	0.671	0.707
1978	0.192	0.285	0.425	0.463	0.509	0.582	0.625	0.659	0.673	0.713
1979	0.190	0.272	0.531	0.567	0.579	0.603	0.652	0.714	0.752	0.803
1980	0.146	0.376	0.548	0.609	0.617	0.635	0.672	0.705	0.781	0.777
1981	0.114	0.315	0.523	0.577	0.643	0.660	0.674	0.707	0.723	0.768
1982	0.152	0.340	0.541	0.606	0.666	0.743	0.737	0.722	0.719	0.775
1983	0.098	0.257	0.479	0.593	0.628	0.659	0.712	0.709	0.705	0.730
1984	0.098	0.162	0.338	0.525	0.625	0.657	0.696	0.715	0.705	0.716
1985	0.111	0.260	0.277	0.416	0.558	0.644	0.677	0.665	0.737	0.715
1986	0.079	0.234	0.349	0.366	0.452	0.581	0.640	0.729	0.777	0.740
1987	0.107	0.210	0.316	0.404	0.411	0.505	0.502	0.706	0.747	0.744
1988	0.100	0.222	0.343	0.408	0.453	0.484	0.584	0.694	0.755	0.770
1989	0.100	0.231	0.375	0.414	0.474	0.509	0.529	0.631	0.753	0.813
1990	0.138	0.224	0.336	0.449	0.487	0.527	0.609	0.570	0.644	0.742
1991	0.187	0.293	0.399	0.462	0.543	0.596	0.616	0.688	0.686	0.768
1992	0.163	0.270	0.378	0.420	0.477	0.522	0.579	0.639	0.642	0.655
1993	0.185	0.270	0.351	0.435	0.477	0.534	0.595	0.644	0.682	0.693
1994	0.158	0.232	0.318	0.399	0.492	0.520	0.587	0.629	0.705	0.665
1995	0.187	0.261	0.343	0.417	0.469	0.544	0.554	0.617	0.704	0.768
1996	0.218	0.254	0.354	0.481	0.482	0.552	0.596	0.644	0.692	0.684
1997	0.199	0.301	0.382	0.451	0.547	0.532	0.571	0.609	0.658	0.685
1998	0.149	0.250	0.373	0.482	0.535	0.560	0.592	0.604	0.656	0.682
1999	0.167	0.266	0.393	0.459	0.529	0.581	0.611	0.618	0.681	0.685
2000	0.200	0.231	0.322	0.443	0.530	0.585	0.614	0.674	0.693	0.678
2001	0.137	0.263	0.359	0.402	0.507	0.580	0.649	0.628	0.663	0.677
2002	0.138	0.220	0.344	0.430	0.471	0.563	0.599	0.645	0.707	0.677
2003	0.129	0.229	0.308	0.435	0.517	0.573	0.635	0.641	0.839	0.677
2004	0.179	0.226	0.342	0.387	0.480	0.501	0.607	0.698	0.572	0.677

Table B5. Stratified mean weight and number per tow (standard) of Atlantic Mackerel from the NEFSC spring bottom trawl survey during 1968-2005.

Year	Kg	Number
1968	5.609	70.869
1969	0.055	0.484
1970	2.2	9.356
1971	3.145	12.668
1972	1.542	8.49
1973	6.746	20.973
1974	0.656	2.241
1975	0.242	3.54
1976	0.254	1.8
1977	0.081	0.287
1978	0.345	0.97
1979	0.089	0.172
1980	0.202	0.559
1981	2.47	5.872
1982	0.854	5.167
1983	0.135	0.884
1984	2.611	16.228
1985	2.232	8.242
1986	1.264	4.178
1987	7.492	35.231
1988	4.133	16.792
1989	1.1	12.273
1990	1.548	10.748
1991	5.604	23.265
1992	4.705	24.275
1993	5.583	26.089
1994	5.987	38.638
1995	5.1	24.387
1996	11.101	40.887
1997	2.494	22.054
1998	3.378	25.11
1999	7.109	50.617
2000	6.934	70.357
2001	15.726	116.454
2002	7.65	35.201
2003	11.082	60.488
2004	8.088	110.683
2005	4.276	32.322

Table B6. Atlantic mackerel number per tow (ln retransformed) at age from the NEFSC Spring bottom trawl survey during 1968-2005

Year	1	2	3	4	5	6	7	8	9	10+
1968	12.9400	0.4150	0.1894	0.0523	0.0164	0.0000	0.0000	0.0000	0.0000	0.0000
1969	0.0297	0.1418	0.0167	0.0058	0.0003	0.0007	0.0005	0.0009	0.0004	0.0004
1970	0.2795	0.1845	1.3910	0.6115	0.1812	0.0617	0.0549	0.0877	0.0827	0.0473
1971	0.3282	0.9409	0.4383	1.1250	0.3929	0.0621	0.0141	0.0073	0.0062	0.0083
1972	0.8719	0.3077	0.5929	0.2261	0.3254	0.0583	0.0112	0.0011	0.0018	0.0004
1973	0.3514	0.3398	0.1758	0.2338	0.1262	0.2846	0.1821	0.1524	0.0460	0.1022
1974	0.3478	0.1796	0.2358	0.0478	0.0985	0.0599	0.2084	0.0912	0.0590	0.0232
1975	0.6544	0.2298	0.0409	0.0226	0.0064	0.0073	0.0043	0.0039	0.0034	0.0000
1976	0.0959	0.3871	0.0710	0.0135	0.0024	0.0006	0.0028	0.0004	0.0019	0.0006
1977	0.0095	0.0472	0.0850	0.0453	0.0154	0.0052	0.0028	0.0070	0.0038	0.0139
1978	0.0502	0.1097	0.1032	0.1943	0.0958	0.0284	0.0110	0.0027	0.0148	0.0177
1979	0.0105	0.0037	0.0072	0.0126	0.0495	0.0144	0.0103	0.0057	0.0057	0.0482
1980	0.0234	0.1877	0.0066	0.0048	0.0233	0.0489	0.0110	0.0107	0.0070	0.0284
1981	0.3355	0.1371	0.4294	0.0476	0.0463	0.1613	0.4041	0.2302	0.1385	0.4021
1982	0.4323	0.1950	0.0215	0.0979	0.0182	0.0102	0.0245	0.0965	0.0440	0.0836
1983	0.2357	0.2873	0.0222	0.0016	0.0036	0.0006	0.0002	0.0014	0.0022	0.0020
1984	0.2598	1.8014	0.6055	0.0415	0.0050	0.0432	0.0036	0.0025	0.0161	0.0837
1985	0.3382	0.0846	1.8513	0.2348	0.0277	0.0107	0.0469	0.0032	0.0097	0.1864
1986	0.1301	0.4497	0.0778	0.5908	0.1177	0.0080	0.0014	0.0196	0.0004	0.0474
1987	1.4842	1.7945	0.8742	0.3719	2.9450	0.4967	0.1427	0.0156	0.1383	0.2560
1988	0.6336	0.4577	0.3666	0.3357	0.3748	1.7688	0.4428	0.0513	0.0478	0.2232
1989	1.5826	1.6407	0.0707	0.2841	0.0087	0.0108	0.0666	0.0086	0.0050	0.0182
1990	1.3003	1.3849	0.5010	0.0157	0.0129	0.0059	0.0004	0.0762	0.0094	0.0157
1991	1.6697	0.8891	1.4843	0.5374	0.2400	0.1144	0.0578	0.0000	0.2685	0.0027
1992	2.6984	2.3787	0.5585	1.0531	0.6272	0.1155	0.1321	0.0312	0.0449	0.2983
1993	0.9331	2.2477	0.9019	0.6031	0.9864	0.4515	0.1389	0.0915	0.2184	0.6286
1994	4.1386	1.7436	2.1139	0.8699	0.2534	0.5039	0.1133	0.0512	0.0105	0.2267
1995	3.1701	3.4871	0.5893	1.1824	0.7122	0.2848	0.7191	0.2258	0.0451	0.1351
1996	4.0058	3.2257	1.3258	0.1481	0.6175	0.4196	0.1927	0.2800	0.1456	0.1220
1997	3.0378	1.1619	0.4485	0.2247	0.0254	0.1244	0.1149	0.0452	0.0702	0.0159
1998	5.6955	3.1199	0.6787	0.2863	0.1211	0.0171	0.0867	0.0633	0.0179	0.0240
1999	5.0097	4.1347	2.9205	0.9221	0.4061	0.1784	0.0498	0.0819	0.0389	0.0191
2000	14.8080	2.4561	1.1156	0.7272	0.2514	0.1189	0.0500	0.0000	0.0194	0.0239
2001	12.4610	26.5960	1.7581	0.3622	0.2115	0.0375	0.0114	0.0093	0.0042	0.0012
2002	1.2662	2.9770	5.7418	0.4438	0.1229	0.0493	0.0192	0.0014	0.0000	0.0000
2003	9.1159	8.3906	2.9148	3.2997	0.4028	0.1207	0.0555	0.0000	0.0000	0.0000
2004	21.9190	3.0060	0.3165	0.1166	0.1516	0.0121	0.0010	0.0000	0.0000	0.0000
2005	1.7745	3.7293	0.9319	0.1697	0.1354	0.3667	0.0258	0.0050	0.0000	0.0000

Table B7. Weight and number per tow (standard) number per tow from the NEFSC winter bottom trawl survey during 1992-2005.

Year	Kg	Number
1992	14.813	47.694
1993	4.265	17.263
1994	0.254	1.161
1995	27.125	74.658
1996	6.828	40.034
1997	3.139	20.792
1998	4.123	18.332
1999	1.675	13.254
2000	1.342	4.676
2001	4.238	25.285
2002	5.528	25.609
2003	24.262	103.576
2004	5.042	59.469
2005	32.047	245.577

Table B8. Number of Atlantic mackerel per tow at age (retransformed) from the NEFSC Winter bottom trawls survey during 1992-2005.

Year	1	2	3	4	5	6	7	8	9	10+
1992	3.0523	1.4908	0.5367	1.6471	1.2904	0.3196	0.4615	0.1702	0.3949	2.1468
1993	0.7766	3.4136	0.9937	0.3717	0.9014	0.6192	0.1061	0.1033	0.249	0.3242
1994	0.3244	0.1053	0.2362	0.1387	0.0284	0.066	0.0116	0.0043	0	0.0043
1995	1.6475	4.0829	0.12502	2.0966	1.693	0.9592	2.0291	0.9036	0.2251	0.5583
1996	3.6854	2.4076	0.9712	0.1034	0.5132	0.3334	0.1294	0.2284	0.0864	0.0235
1997	2.1225	2.0327	1.5196	0.6153	0.0429	0.2684	0.2356	0.1026	0.1556	0.0283
1998	1.7823	2.8163	0.8565	0.6274	0.3459	0.076	0.1595	0.2664	0.0381	0.1187
1999	1.2908	0.6953	0.8	0.2662	0.1451	0.0802	0.0253	0.0498	0.0147	0.0164
2000	0.3437	0.8842	0.5921	0.4236	0.1798	0.0954	0.0365	0	0.01	0.0377
2001	2.0193	2.9817	0.5373	0.2485	0.3259	0.0922	0.0507	0.0282	0.011	0.0012
2002	1.871	0.7383	0.0269	0.412	0.1711	0.169	0.0633	0.009	0	0.0005
2003	15.955	4.4698	2.0118	2.4065	0.5303	0.3372	0.2546	0.0452	0	0
2004	11.334	2.1515	0.2461	0.2624	0.6209	0.0871	0.0102	0.001	0.001	0
2005	34.691	38.056	3.822	0.5594	0.4275	1.0818	0.0235	0.0122	0	0

Table B9. Likelihood components and emphasis coefficients in ASAP base case model run

Likelihood Component	**Lambda**
Landings	1000
SR relationship	1
Spring survey	6.74
Recruitment CV	0.5
CAA	50

Table B10. Likelihood components and emphasis coefficients in ASAP model run to address retrospective patterning

Likelihood Component	**Lambda**
Landings	1000
SR relationship	10
Fishery Selectivity	10
Spring survey	6.74
Recruitment CV	0.5, and 0.01 in 2000&2004
CAA	50

Table B11. Likelihood results for various model components for preliminary, base case, and sensitivity runs of the ASAP model.

ASAP model runs					**Sensitivity model runs**		
	spring only	**spring split**	**spring split SR on**	**Base Case**	**winter & spring**	**retro fix 95-04**	**est selectivity 62-94, 95-04**
obj_fun	4327.18	3943.78	2499.00	1580.08	3241.43	1692.53	1540.11
Catch_Fleet_Total	3.17	2.57	1.03	0.50	6.78	0.60	0.99
CAA_proportions	1048.16	998.27	317.64	254.81	310.93	350.87	211.44
Index_Fit_Total	3275.85	2942.94	2075.09	1221.98	2777.30	1253.53	1219.76
Winter					597.87		
Spring no split	3275.85						
Spring1 split		1657.48	1150.56	653.71	1199.72	685.56	655.31
Spring2 split		1285.46	924.53	568.27	979.71	567.97	564.46

Table B12. Parameter file from ASAP base case model run with parameter name, parameter estimate (value), and standard deviation (std)

index	name	value	std
1	log_Fmult_year1	-3.15E+00	1.41E-01
2	log_Fmult_devs	1.20E-01	3.91E-02
3	log_Fmult_devs	2.65E-01	3.82E-02
4	log_Fmult_devs	8.42E-02	3.65E-02
5	log_Fmult_devs	1.59E-01	4.05E-02
6	log_Fmult_devs	1.67E-01	4.96E-02
7	log_Fmult_devs	1.59E-01	5.49E-02
8	log_Fmult_devs	8.20E-02	4.64E-02
9	log_Fmult_devs	4.10E-01	3.68E-02
10	log_Fmult_devs	4.85E-01	3.43E-02
11	log_Fmult_devs	6.78E-02	3.40E-02
12	log_Fmult_devs	4.07E-01	3.50E-02
13	log_Fmult_devs	5.72E-02	3.61E-02
14	log_Fmult_devs	6.77E-02	3.88E-02
15	log_Fmult_devs	-8.90E-02	4.21E-02
16	log_Fmult_devs	-1.29E+00	3.86E-02
17	log_Fmult_devs	-1.00E+00	3.45E-02
18	log_Fmult_devs	2.05E-02	3.33E-02
19	log_Fmult_devs	-2.58E-01	3.48E-02
20	log_Fmult_devs	1.34E-01	3.57E-02
21	log_Fmult_devs	-1.11E-01	3.60E-02
22	log_Fmult_devs	-6.07E-02	4.09E-02
23	log_Fmult_devs	-5.93E-02	4.00E-02
24	log_Fmult_devs	4.25E-01	3.90E-02
25	log_Fmult_devs	-1.07E-01	3.33E-02
26	log_Fmult_devs	3.52E-01	3.35E-02
27	log_Fmult_devs	3.09E-01	3.46E-02
28	log_Fmult_devs	-2.14E-01	3.61E-02
29	log_Fmult_devs	-1.89E-01	3.68E-02
30	log_Fmult_devs	-7.82E-02	3.65E-02
31	log_Fmult_devs	-6.40E-01	3.39E-02
32	log_Fmult_devs	-6.99E-02	3.56E-02
33	log_Fmult_devs	7.39E-02	3.38E-02
34	log_Fmult_devs	-1.02E-01	3.42E-02
35	log_Fmult_devs	3.07E-01	3.45E-02
36	log_Fmult_devs	-3.79E-02	3.51E-02
37	log_Fmult_devs	-6.95E-02	3.43E-02
38	log_Fmult_devs	-2.51E-01	3.53E-02
39	log_Fmult_devs	-5.82E-01	3.76E-02
40	log_Fmult_devs	4.95E-01	4.11E-02
41	log_Fmult_devs	2.29E-01	3.75E-02
42	log_Fmult_devs	2.29E-01	3.37E-02
43	log_Fmult_devs	2.60E-01	3.74E-02
44	log_recruit_devs	-9.64E-01	1.80E-01
45	log_recruit_devs	-8.62E-01	2.50E-01
46	log_recruit_devs	-7.25E-01	2.20E-01

47	log_recruit_devs	-1.94E-01	2.02E-01
48	log_recruit_devs	7.81E-01	1.84E-01
49	log_recruit_devs	1.33E+00	1.67E-01
50	log_recruit_devs	2.40E+00	1.38E-01
51	log_recruit_devs	7.20E-01	1.23E-01
52	log_recruit_devs	1.00E+00	1.33E-01
53	log_recruit_devs	-3.52E-02	1.56E-01
54	log_recruit_devs	2.89E-01	1.55E-01
55	log_recruit_devs	2.63E-01	1.58E-01
56	log_recruit_devs	8.22E-01	1.25E-01
57	log_recruit_devs	1.07E+00	9.80E-02
58	log_recruit_devs	-2.53E-01	1.19E-01
59	log_recruit_devs	-1.37E+00	1.39E-01
60	log_recruit_devs	-1.79E+00	1.45E-01
61	log_recruit_devs	-3.42E-01	1.17E-01
62	log_recruit_devs	-1.58E+00	1.37E-01
63	log_recruit_devs	-5.04E-01	1.25E-01
64	log_recruit_devs	5.84E-01	1.07E-01
65	log_recruit_devs	1.59E+00	8.67E-02
66	log_recruit_devs	-9.97E-01	1.37E-01
67	log_recruit_devs	-1.29E+00	1.38E-01
68	log_recruit_devs	-1.05E+00	1.38E-01
69	log_recruit_devs	-1.06E+00	1.36E-01
70	log_recruit_devs	4.07E-02	1.11E-01
71	log_recruit_devs	5.02E-01	9.94E-02
72	log_recruit_devs	-3.56E-01	1.17E-01
73	log_recruit_devs	5.24E-03	1.07E-01
74	log_recruit_devs	-6.88E-02	1.12E-01
75	log_recruit_devs	-1.26E+00	1.33E-01
76	log_recruit_devs	-1.44E-01	1.11E-01
77	log_recruit_devs	-1.80E-02	1.08E-01
78	log_recruit_devs	-1.72E-01	1.13E-01
79	log_recruit_devs	1.68E-01	1.11E-01
80	log_recruit_devs	-2.11E-01	1.22E-01
81	log_recruit_devs	3.51E-03	1.27E-01
82	log_recruit_devs	1.82E+00	1.12E-01
83	log_recruit_devs	2.72E-01	1.49E-01
84	log_recruit_devs	-1.13E-01	1.82E-01
85	log_recruit_devs	6.28E-01	2.03E-01
86	log_recruit_devs	1.08E+00	2.47E-01
87	log_N_year1_devs	-7.55E-01	2.74E-01
88	log_N_year1_devs	9.70E-01	1.78E-01
89	log_N_year1_devs	-2.89E-01	2.77E-01
90	log_N_year1_devs	-1.79E+00	7.31E-01
91	log_N_year1_devs	-1.39E+00	6.93E-01
92	log_N_year1_devs	-2.28E+00	4.77E-01
93	log_q_year1	-8.40E+00	1.06E-01
94	log_q_year1	-7.12E+00	1.05E-01
95	log_q_year1	-7.12E+00	1.06E-01
96	log_q_year1	-6.90E+00	1.11E-01

97	log_q_year1	-6.40E+00	1.17E-01
98	log_q_year1	-5.99E+00	1.26E-01
99	log_q_year1	-6.96E+00	1.46E-01
100	log_q_year1	-7.28E+00	1.66E-01
101	log_q_year1	-6.92E+00	1.65E-01
102	log_q_year1	-6.59E+00	1.65E-01
103	log_q_year1	-6.34E+00	1.67E-01
104	log_q_year1	-6.42E+00	1.69E-01
105	log_q_year1	-6.25E+00	1.70E-01
106	log_q_year1	-7.33E+00	1.73E-01
107	log_SRR_virgin	7.38E+00	1.43E-01
108	SRR_steepness	5.07E-01	1.09E-01
109	SSB	2.98E+02	4.09E+01
110	SSB	3.02E+02	4.11E+01
111	SSB	3.16E+02	4.26E+01
112	SSB	3.36E+02	4.46E+01
113	SSB	3.70E+02	4.55E+01
114	SSB	4.45E+02	4.55E+01
115	SSB	8.31E+02	6.16E+01
116	SSB	1.36E+03	6.49E+01
117	SSB	1.60E+03	6.67E+01
118	SSB	1.65E+03	6.52E+01
119	SSB	1.70E+03	7.37E+01
120	SSB	1.23E+03	5.92E+01
121	SSB	9.38E+02	5.33E+01
122	SSB	7.23E+02	4.37E+01
123	SSB	6.63E+02	4.49E+01
124	SSB	6.77E+02	6.12E+01
125	SSB	7.82E+02	7.51E+01
126	SSB	8.03E+02	7.80E+01
127	SSB	7.98E+02	7.70E+01
128	SSB	7.74E+02	7.46E+01
129	SSB	7.79E+02	7.46E+01
130	SSB	8.59E+02	8.11E+01
131	SSB	1.09E+03	1.05E+02
132	SSB	1.36E+03	1.37E+02
133	SSB	1.30E+03	1.39E+02
134	SSB	1.15E+03	1.29E+02
135	SSB	1.07E+03	1.29E+02
136	SSB	9.62E+02	1.26E+02
137	SSB	1.03E+03	1.42E+02
138	SSB	1.25E+03	1.79E+02
139	SSB	1.27E+03	1.91E+02
140	SSB	1.16E+03	1.77E+02
141	SSB	1.08E+03	1.68E+02
142	SSB	1.06E+03	1.66E+02
143	SSB	1.14E+03	1.82E+02
144	SSB	1.17E+03	1.90E+02
145	SSB	1.19E+03	1.97E+02
146	SSB	1.26E+03	2.11E+02

147	SSB	1.33E+03	2.22E+02
148	SSB	1.85E+03	3.10E+02
149	SSB	2.27E+03	3.89E+02
150	SSB	2.35E+03	4.12E+02
151	SSB	2.32E+03	4.13E+02
152	recruits	3.32E+02	5.86E+01
153	recruits	1.78E+02	3.74E+01
154	recruits	2.06E+02	3.68E+01
155	recruits	3.60E+02	5.47E+01
156	recruits	9.91E+02	1.21E+02
157	recruits	1.81E+03	1.91E+02
158	recruits	5.85E+03	3.47E+02
159	recruits	1.46E+03	1.61E+02
160	recruits	2.27E+03	2.14E+02
161	recruits	8.40E+02	1.04E+02
162	recruits	1.17E+03	1.33E+02
163	recruits	1.15E+03	1.28E+02
164	recruits	1.85E+03	1.68E+02
165	recruits	2.16E+03	1.88E+02
166	recruits	5.22E+02	6.44E+01
167	recruits	1.65E+02	2.35E+01
168	recruits	1.09E+02	1.63E+01
169	recruits	4.93E+02	6.42E+01
170	recruits	1.44E+02	2.18E+01
171	recruits	4.23E+02	6.15E+01
172	recruits	1.24E+03	1.65E+02
173	recruits	3.41E+03	4.01E+02
174	recruits	2.65E+02	4.54E+01
175	recruits	2.16E+02	3.89E+01
176	recruits	2.91E+02	5.12E+01
177	recruits	2.85E+02	5.02E+01
178	recruits	8.28E+02	1.31E+02
179	recruits	1.28E+03	1.99E+02
180	recruits	5.25E+02	9.06E+01
181	recruits	7.71E+02	1.31E+02
182	recruits	7.60E+02	1.31E+02
183	recruits	2.31E+02	4.30E+01
184	recruits	6.91E+02	1.21E+02
185	recruits	7.66E+02	1.35E+02
186	recruits	6.52E+02	1.18E+02
187	recruits	9.38E+02	1.69E+02
188	recruits	6.48E+02	1.21E+02
189	recruits	8.07E+02	1.52E+02
190	recruits	5.04E+03	9.36E+02
191	recruits	1.09E+03	2.22E+02
192	recruits	8.04E+02	1.79E+02
193	recruits	1.76E+03	4.21E+02
194	recruits	2.79E+03	7.92E+02
195	plus_group	5.63E+01	2.63E+01
196	plus_group	6.81E+01	2.34E+01

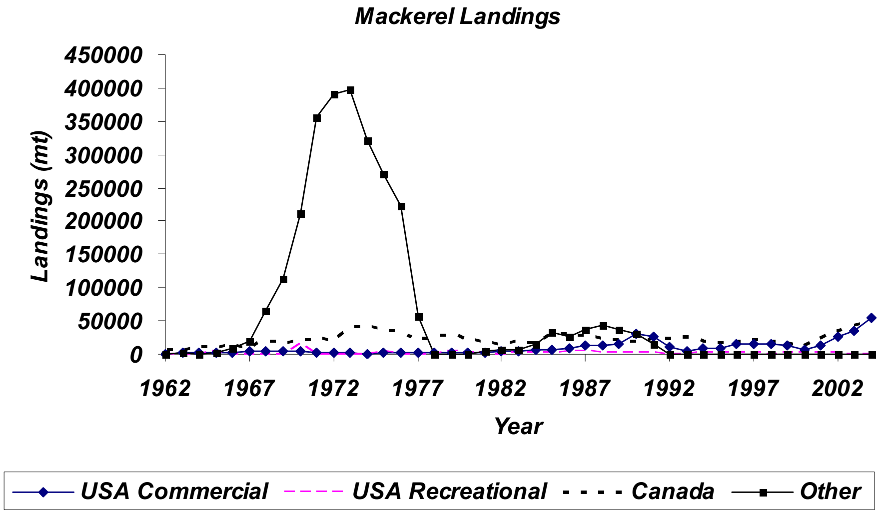
197	plus_group	6.84E+01	1.99E+01
198	plus_group	1.17E+02	2.47E+01
199	plus_group	3.01E+02	5.05E+01
200	plus_group	2.63E+02	4.57E+01
201	plus_group	2.67E+02	4.63E+01
202	plus_group	2.31E+02	3.96E+01
203	plus_group	2.07E+02	3.27E+01
204	plus_group	2.03E+02	2.85E+01
205	plus_group	2.61E+02	3.23E+01
206	plus_group	3.57E+02	3.94E+01
207	plus_group	6.35E+02	6.48E+01
208	plus_group	3.94E+02	4.97E+01
209	plus_group	2.78E+02	4.15E+01
210	plus_group	1.66E+02	2.93E+01
211	plus_group	1.66E+02	2.88E+01
212	plus_group	1.99E+02	3.13E+01
213	plus_group	3.31E+02	4.38E+01
214	plus_group	5.92E+02	6.80E+01
215	plus_group	5.73E+02	6.48E+01
216	plus_group	4.90E+02	5.57E+01
217	plus_group	4.13E+02	4.72E+01
218	plus_group	4.49E+02	5.01E+01
219	plus_group	3.84E+02	4.33E+01
220	plus_group	4.02E+02	4.59E+01
221	plus_group	6.02E+02	7.45E+01
222	plus_group	1.21E+03	1.65E+02
223	plus_group	9.78E+02	1.42E+02
224	plus_group	7.98E+02	1.23E+02
225	plus_group	6.79E+02	1.10E+02
226	plus_group	6.02E+02	9.93E+01
227	plus_group	6.74E+02	1.12E+02
228	plus_group	8.51E+02	1.42E+02
229	plus_group	8.12E+02	1.37E+02
230	plus_group	8.39E+02	1.45E+02
231	plus_group	8.58E+02	1.51E+02
232	plus_group	7.38E+02	1.33E+02
233	plus_group	7.66E+02	1.39E+02
234	plus_group	8.19E+02	1.49E+02
235	plus_group	8.27E+02	1.51E+02
236	plus_group	9.06E+02	1.67E+02
237	plus_group	8.85E+02	1.65E+02
238	MSY	8.95E+01	0.00E+00
239	SSB_ratio	7.79E+00	1.58E+00
240	proj_SSB_ratio	6.85E+00	0.00E+00
241	SSmsy_ratio	3.61E+00	6.42E-01
242	Fmsy_ratio	3.08E-01	0.00E+00
243	MSYp	8.95E+01	0.00E+00

Table B13. Projection for SSB (000 mt) and landings (000 mt) during 2006-2008 for the northwest Atlantic stock of mackerel.

Year	SSB	F	Land
2005	2450.68	0.04	95.00
2006	2640.21	0.12	273.29
2007	2304.02	0.12	238.79
2008	2043.44	0.12	211.99

MACKEREL FIGURES

A.



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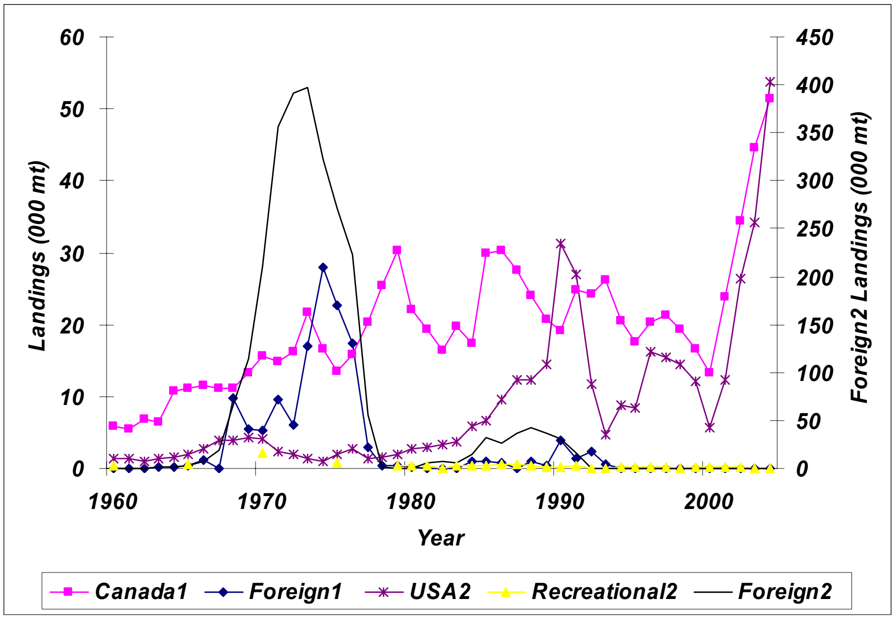

Figure B1. **A.** Landings of Atlantic mackerel in NAFO SA 2-6 during 1962-2004 by USA commercial, USA recreational, Canada, and other countries. **B.** Landings by Canadian vessels (Canada1) or foreign countries (Foreign1) in Canadian waters (SA 2-4). Landings by USA vessels (USA2), recreational sources (Recreational2), or foreign countries (Foreign2) in USA waters (SA5-6).

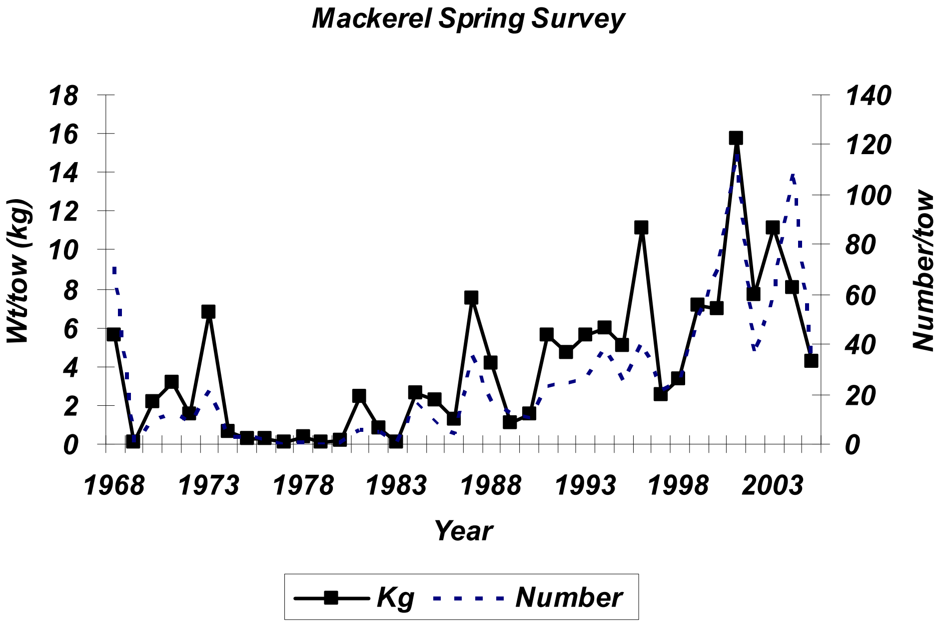

Figure B2. Mackerel Spring bottom trawl survey indices in wt/tow and number/tow during 1968-2005.

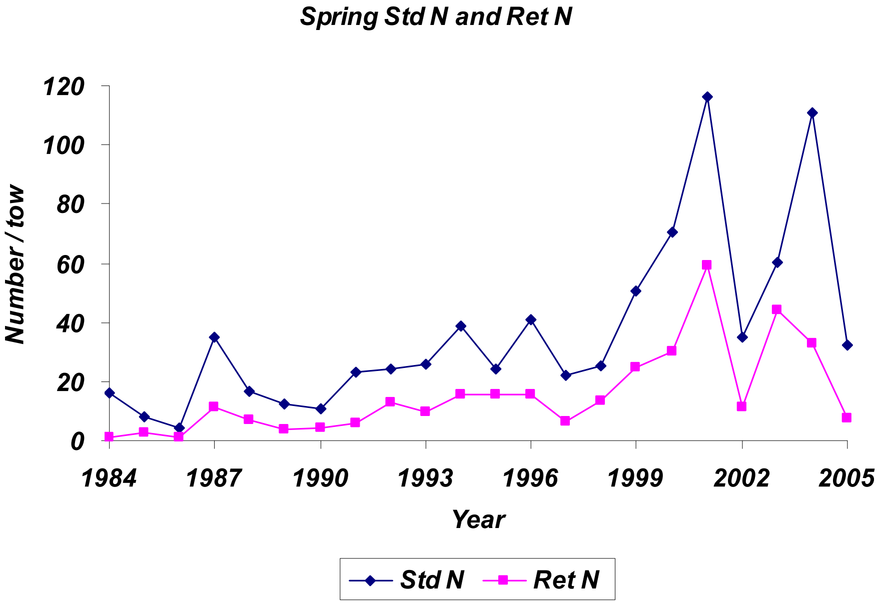

Figure B3. Mackerel Spring bottom trawl survey indices number/tow (standard-std and log retransformed-ret) during 1984-2005.

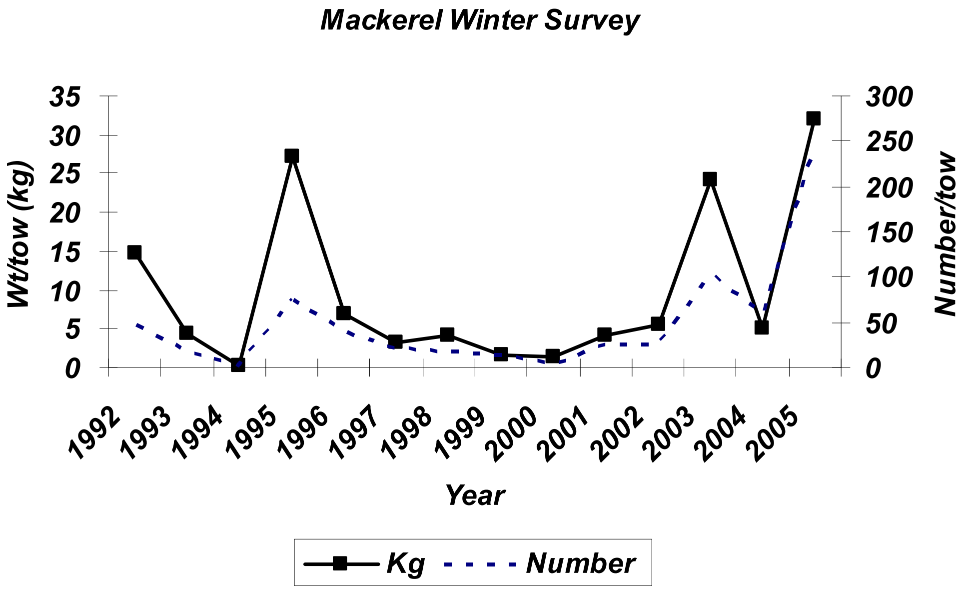

Figure B4. Mackerel winter bottom trawl survey indices in wt/tow and number/tow during 1992-2005.

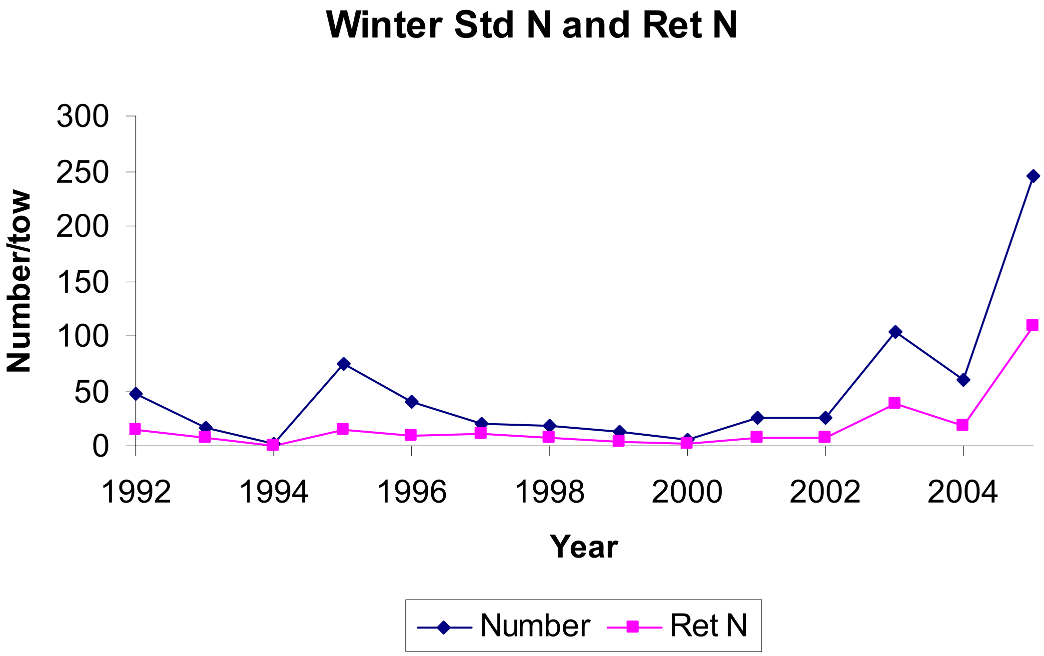

Figure B5. Mackerel winter survey indices in number/tow (standard-std and log retransformed-ret) during 1992-2005.

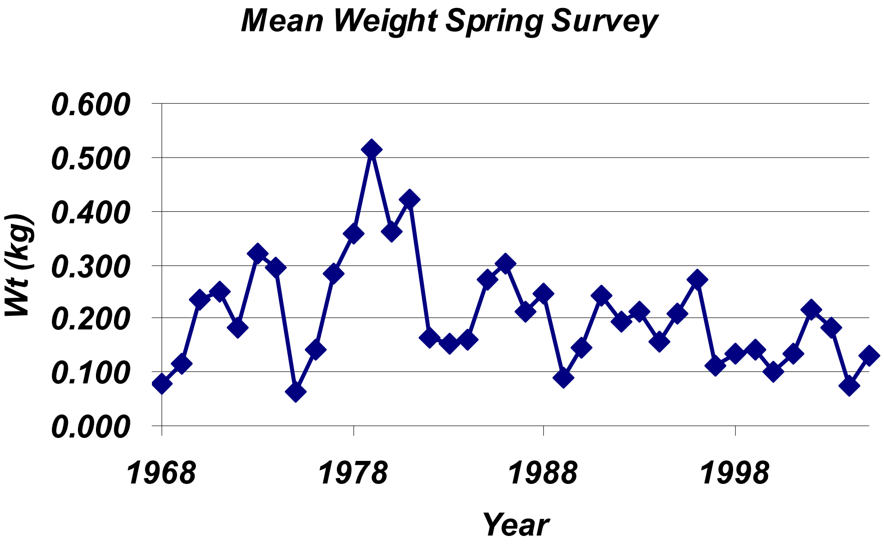

Figure B6. Average weight (kg) of Atlantic mackerel from NEFSC spring surveys during 1968-2005.

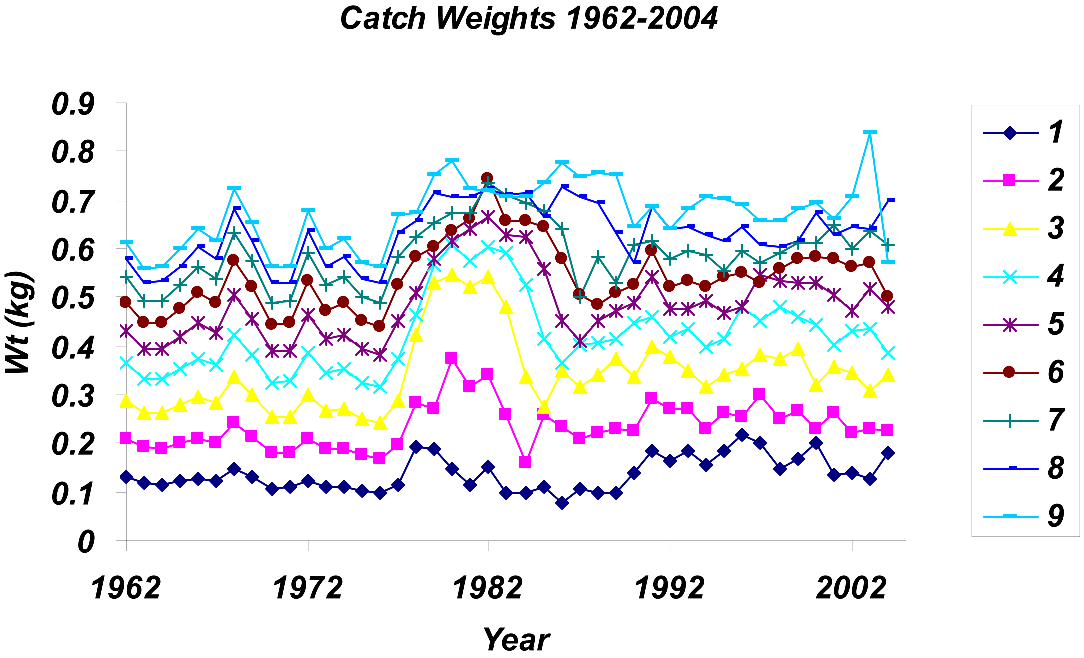

Figure B7. Landed weight (kg) of Atlantic mackerel from USA and Canadian fisheries in NAFO SA 2-6 during 1962-2004.

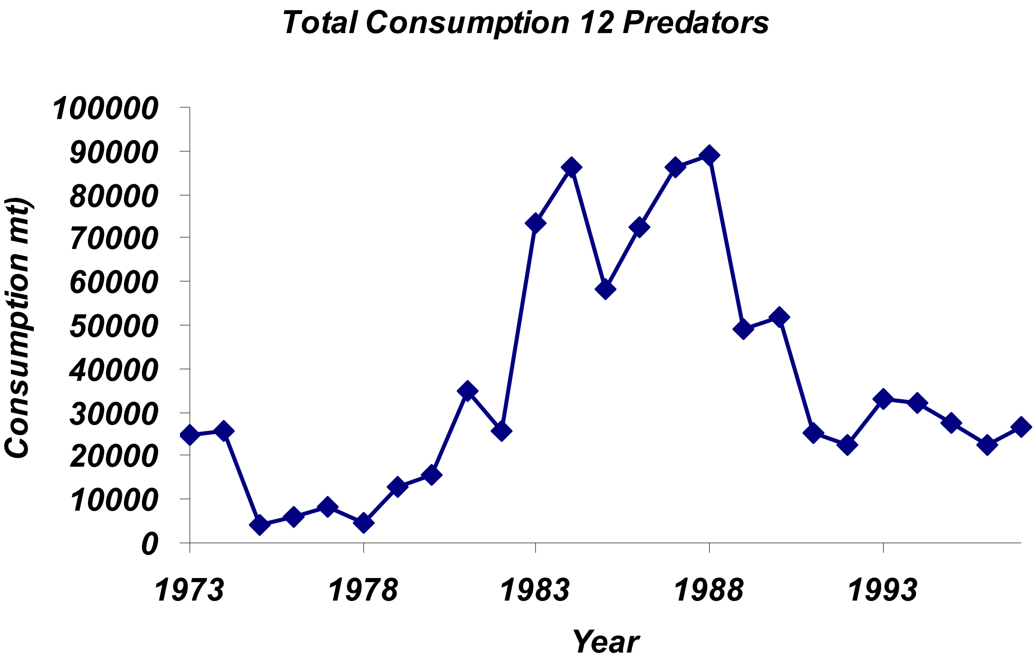

Figure B8. Consumption of Atlantic mackerel by 12 picivorous fish in the Mid-Atlantic-gulf of Maine region during 1973-1997.

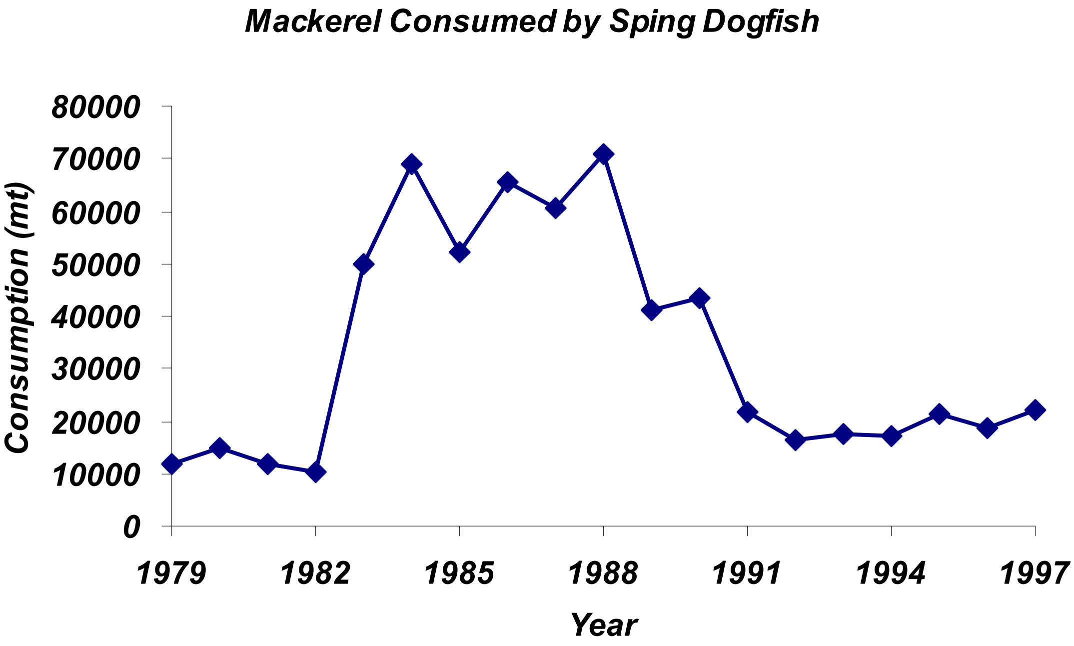

Figure B9. Consumption of Atlantic mackerel by spiny dogfish in the Mid-Atlantic-Gulf of Maine region during 1979-1997.

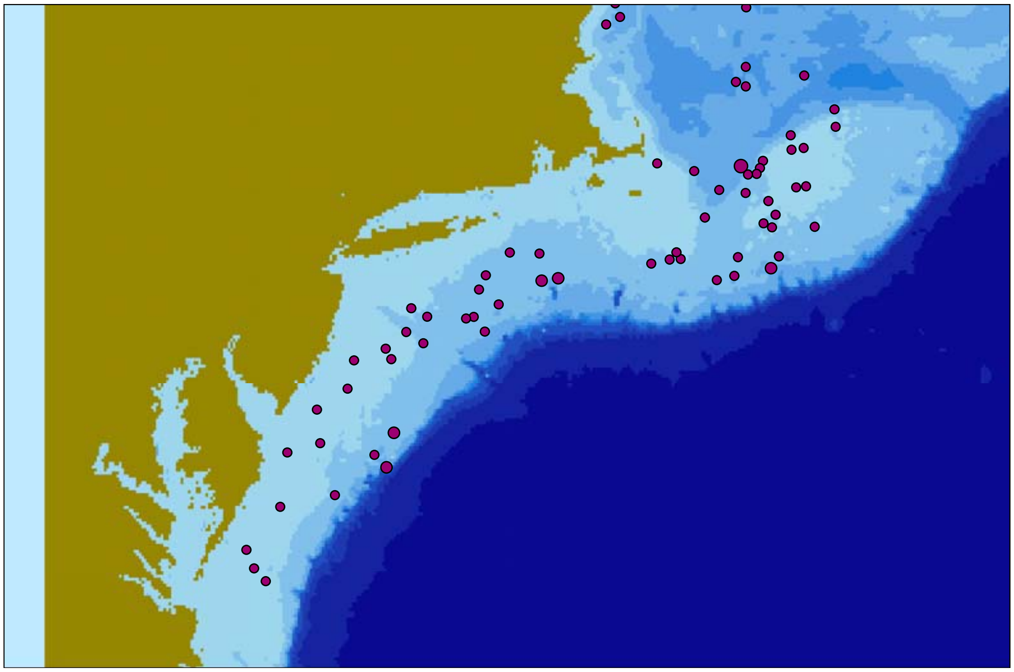

Figure B10. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2002.

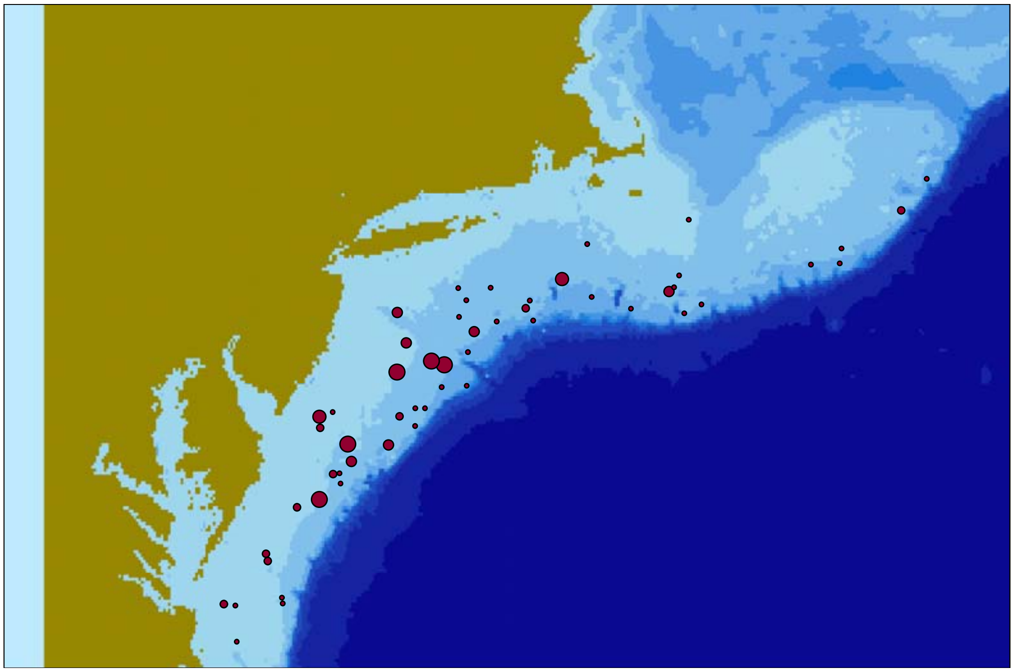

Figure B11. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2003.

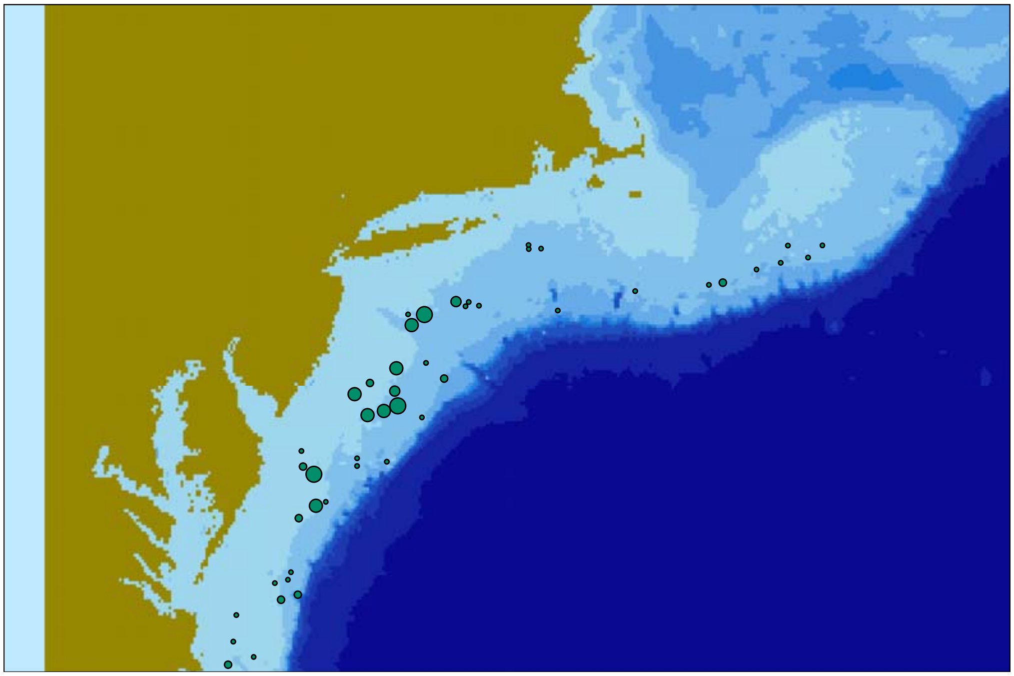

Figure B12. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2004

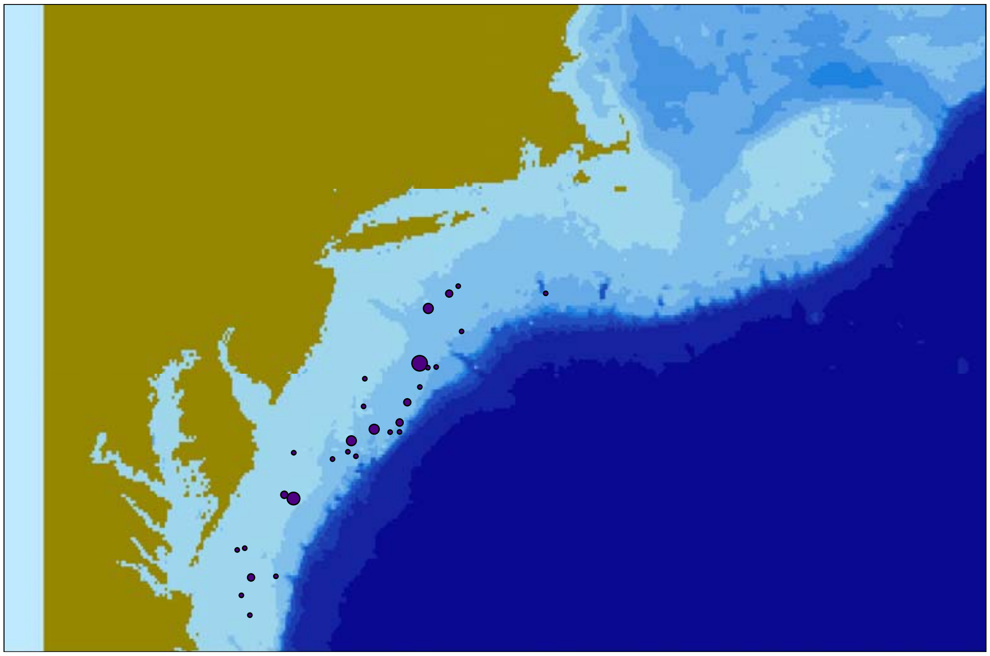

Figure B13. Distribution of mackerel during the spring NEFSC bottom trawl survey in 2005.

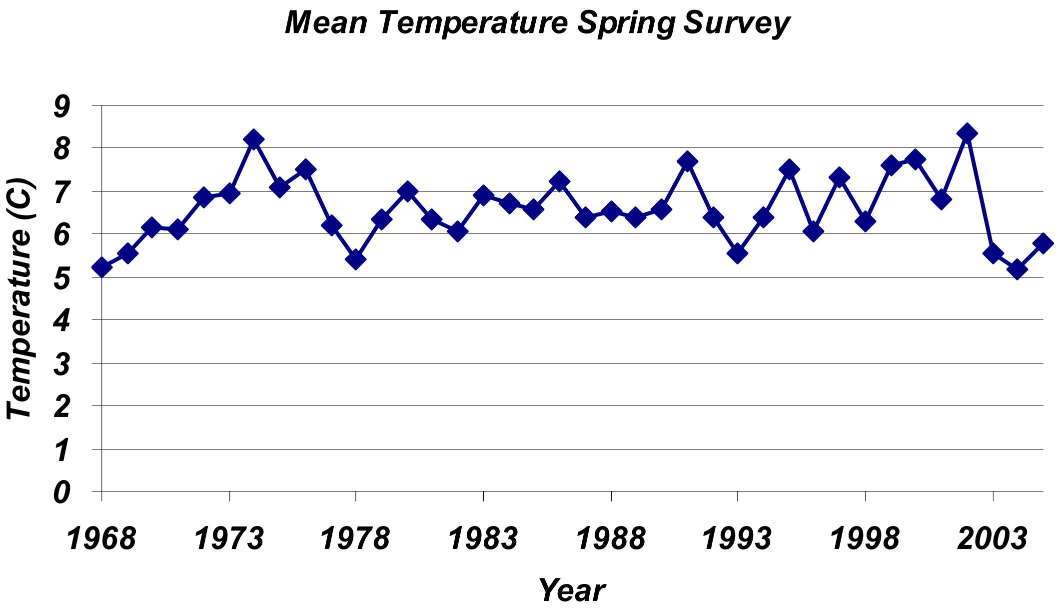

Figure B14. Average temperature from the NEFSC spring survey during 1968-2005.

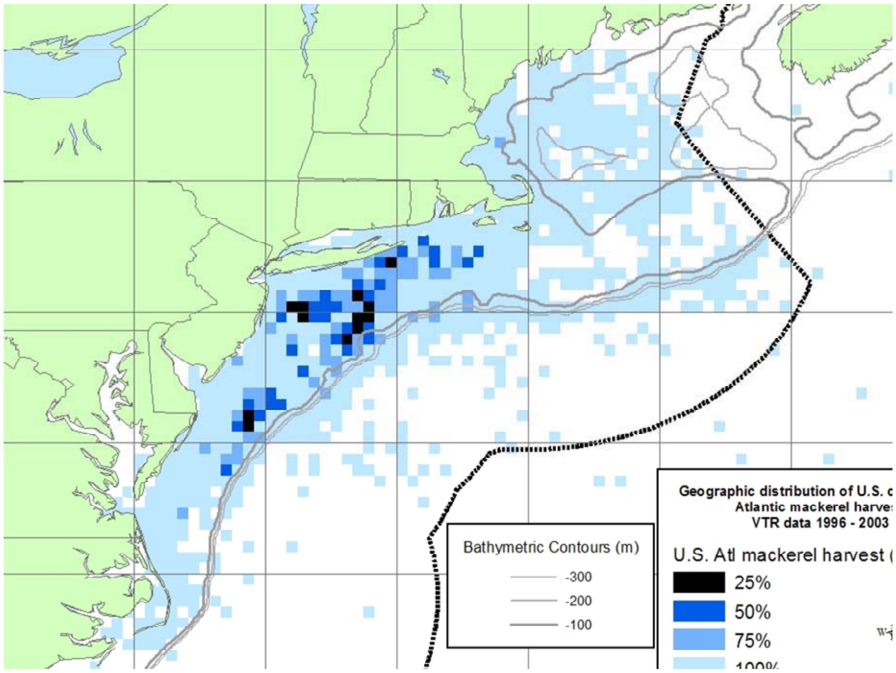

Figure B15. Map of fishing activity for mackerel during 1996-2003.

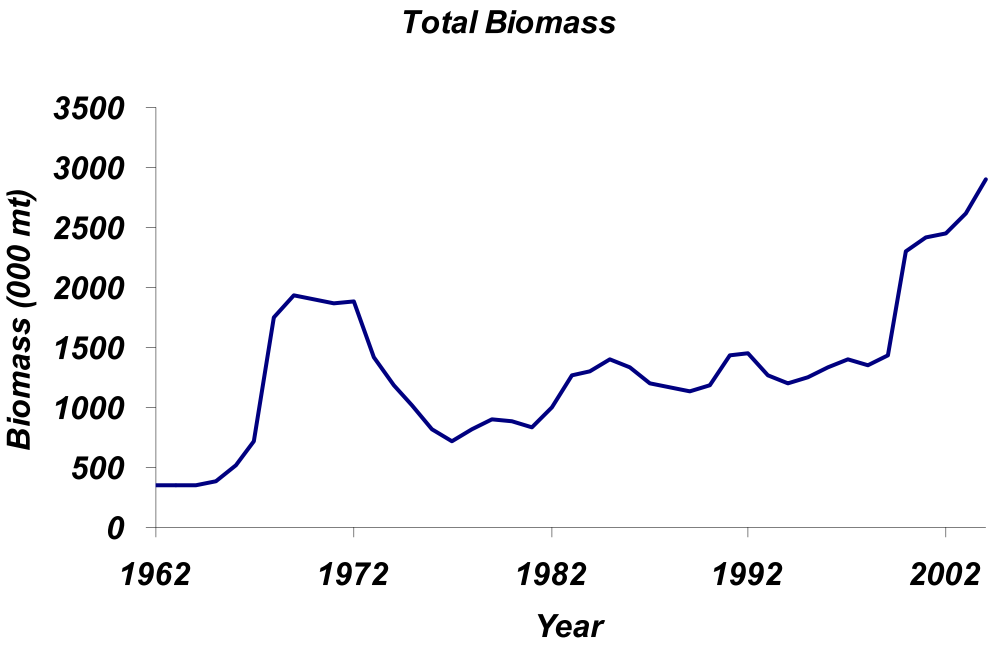

Figure B 16. Total biomass for Atlantic mackerel during 1962-2004 from the ASAP base model run.

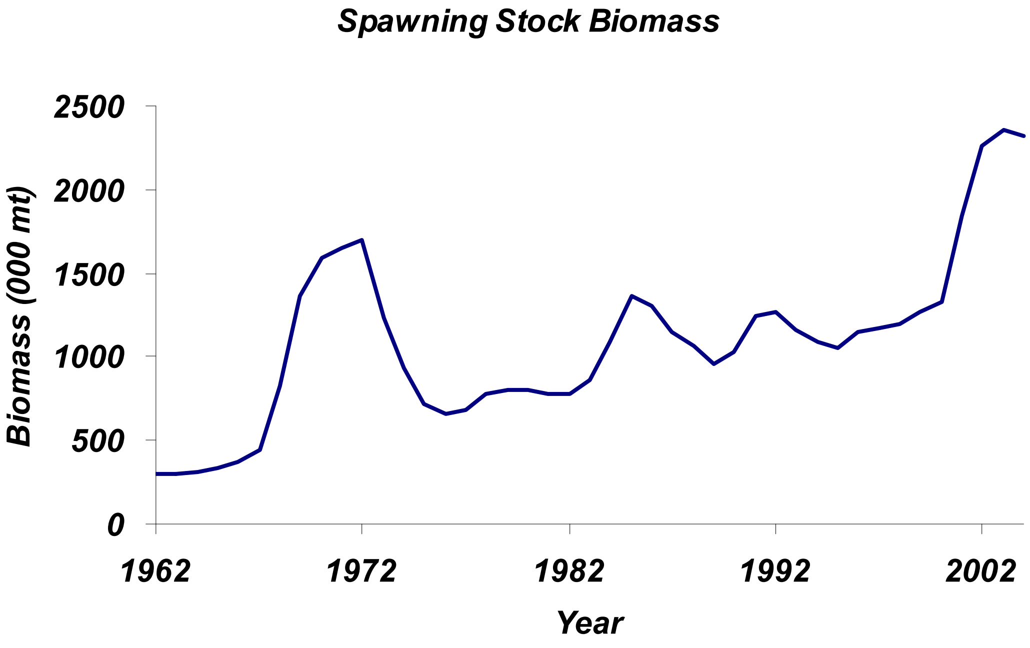

Figure B17. Spawning stock biomass for Atlantic mackerel during 1962-2004 from the ASAP base model run.

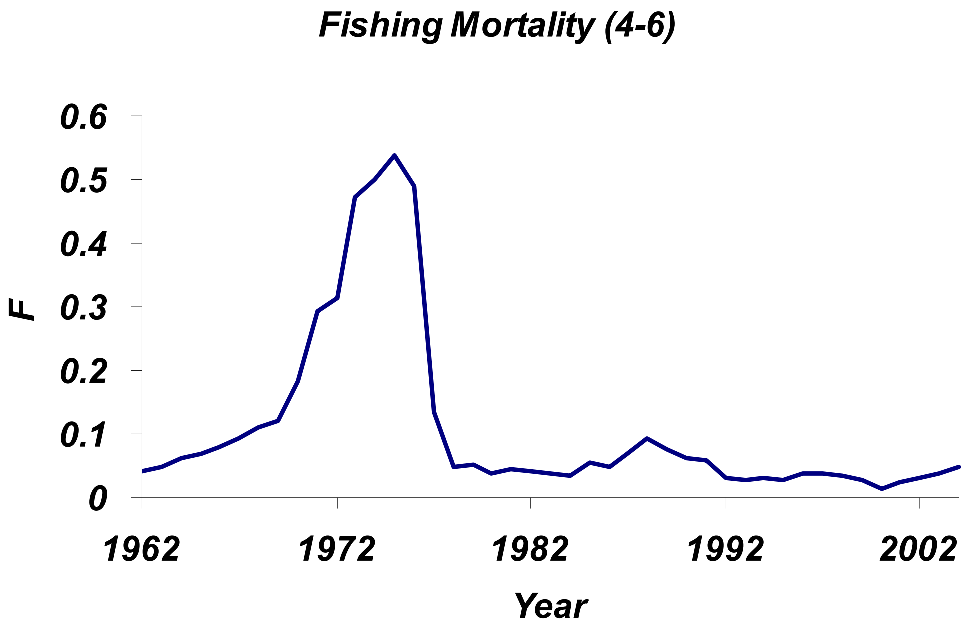

Figure B18. Fishing mortality for Atlantic mackerel during 1962-2004 from the ASAP base model run.

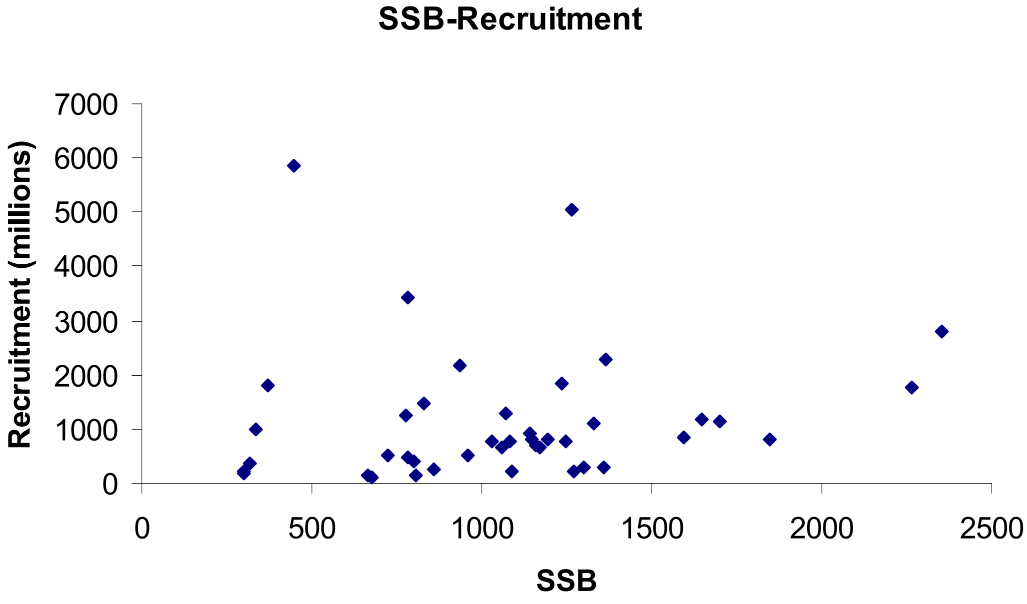

Figure B19. Stock recruitment for Atlantic mackerel during 1962-2004 from the ASAP base model run

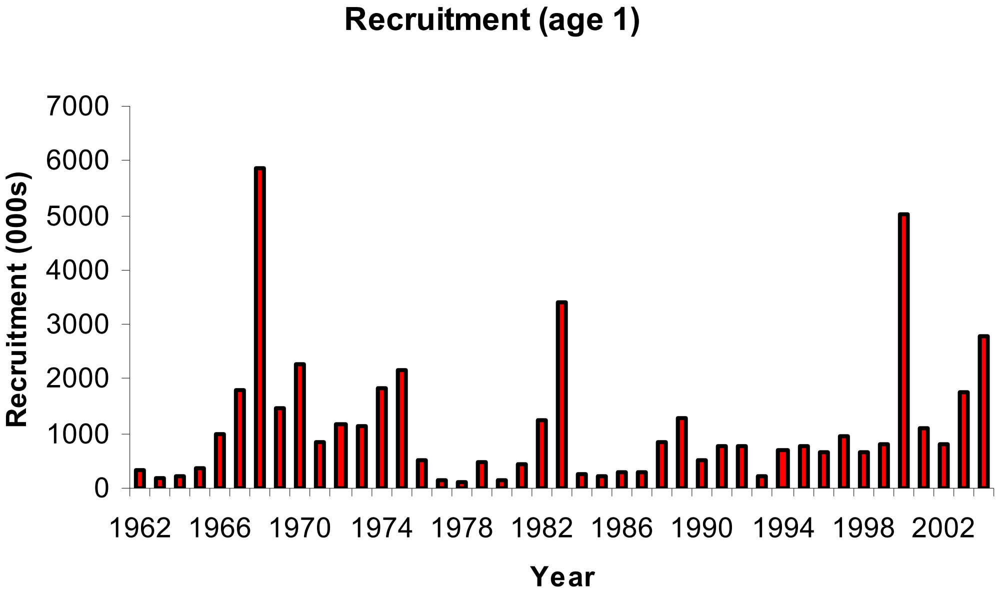

Figure B20. Recruitment (age 1) for Atlantic mackerel during 1962-2004 from the ASAP base model run.

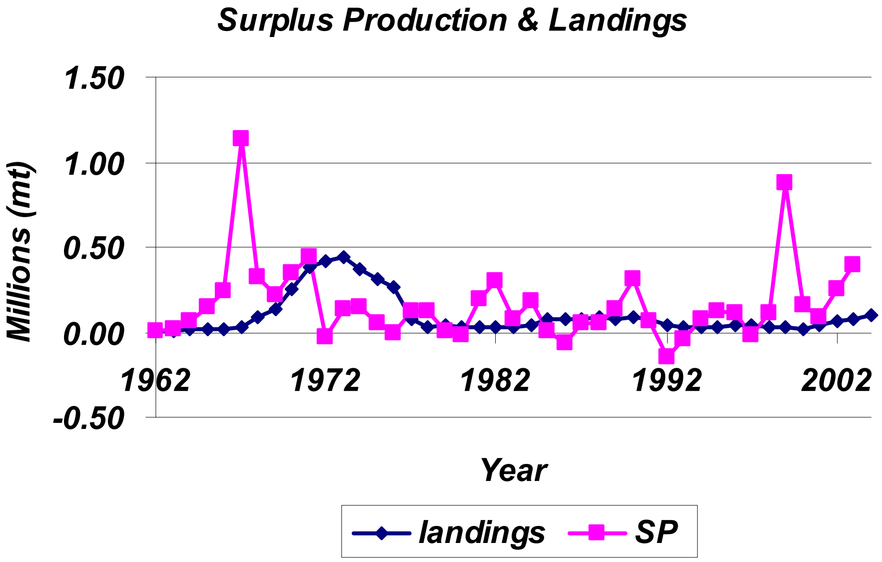

Figure B21. Surplus production and landings of Atlantic mackerel during 1962-2004 from the ASAP base model run.

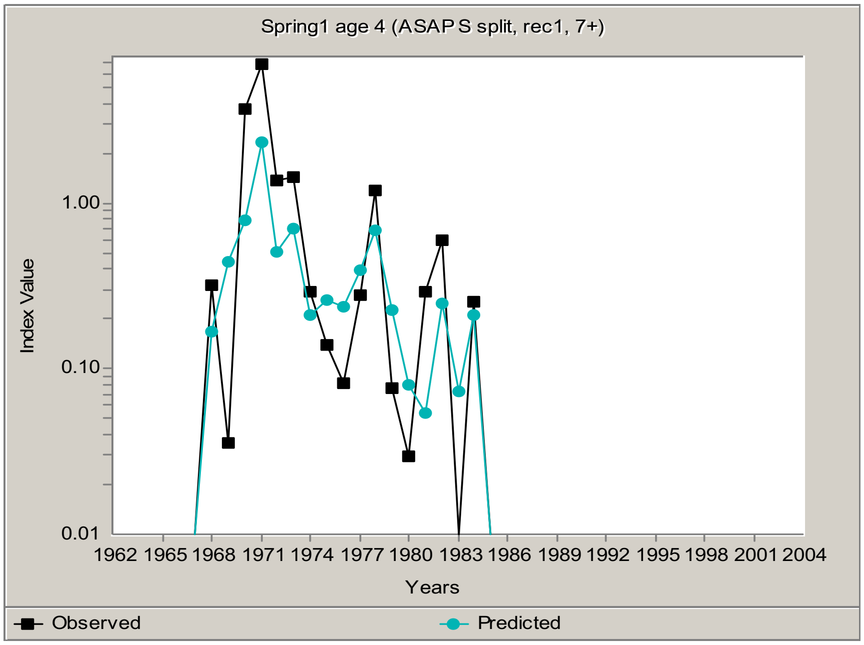

Figure B22. Spring survey observed vs. predicted series (1968-1984, age 4) for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

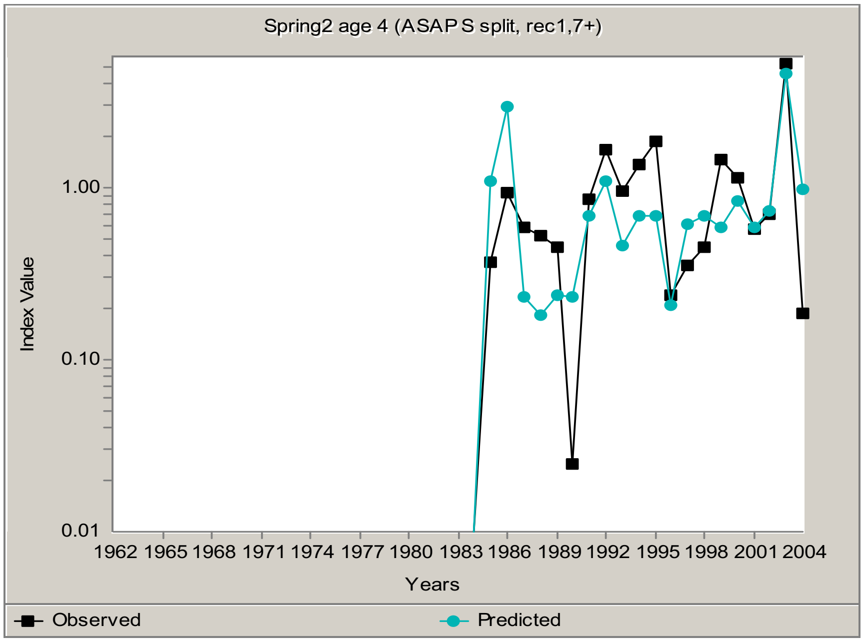

Figure B23. Spring survey observed vs predicted series (1985-2004, age 4) for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

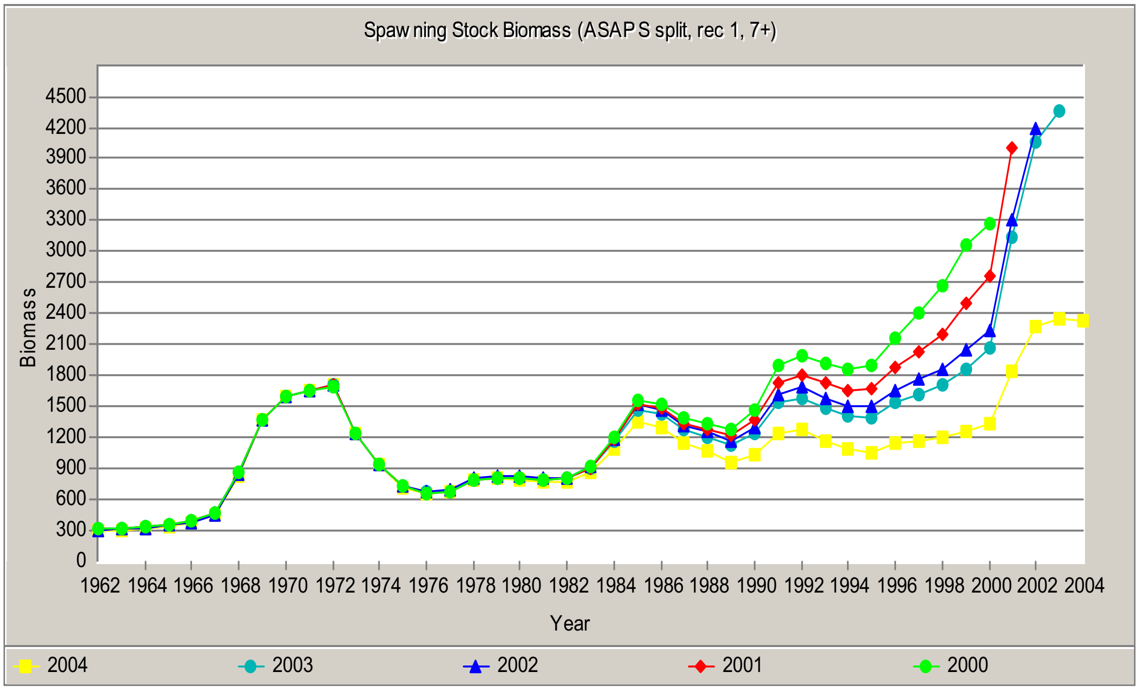

Figure B24. Retrospective pattern for SSB for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

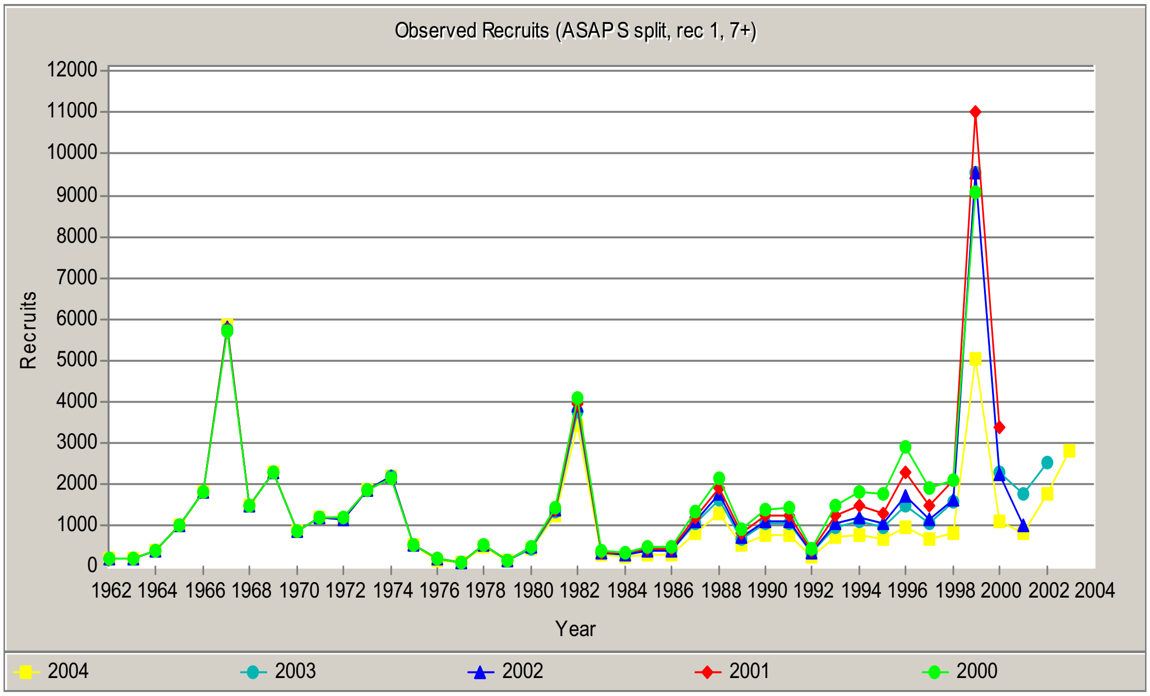

Figure B25. Retrospective pattern for recruitment for the base case ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), and ages aggregated to 7+.

APPENDIX B1: Trial runs for the VPA and ASAP models.

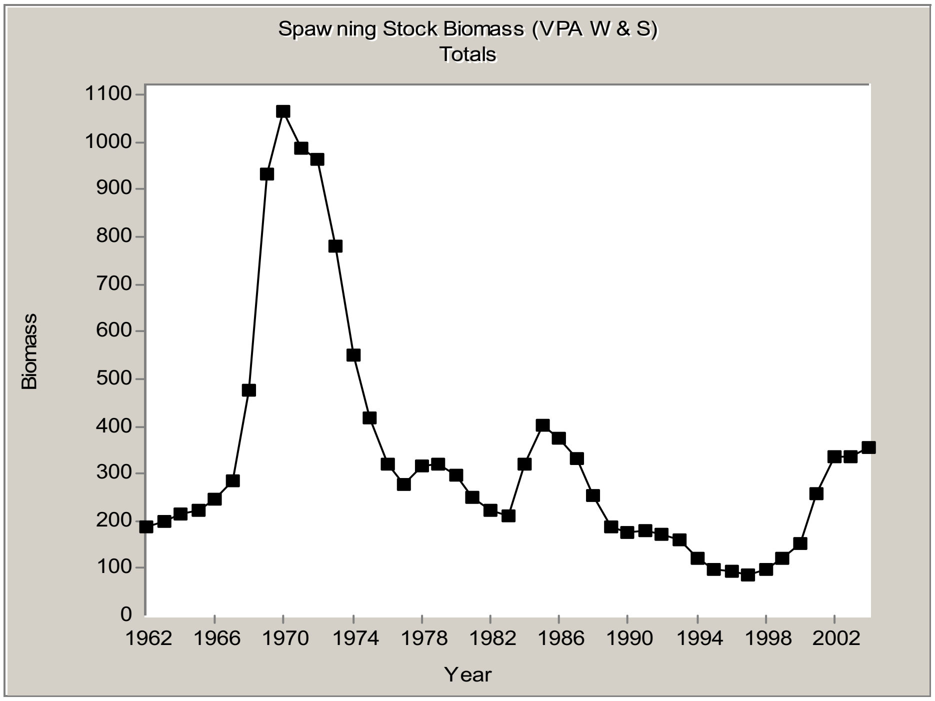

Figure 1 (APPENDIX B1). Spawning stock biomass for a VPA trial run with the winter and spring survey indices.

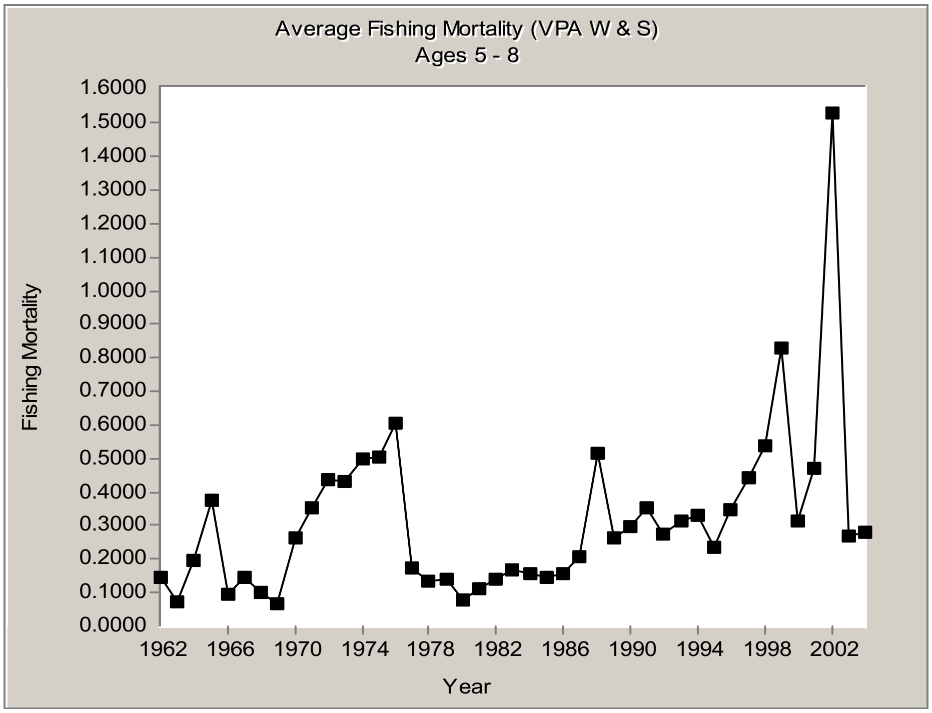

Figure 2 (APPENDIX B1). Fishing mortality for a VPA trial run with the winter and spring indices.

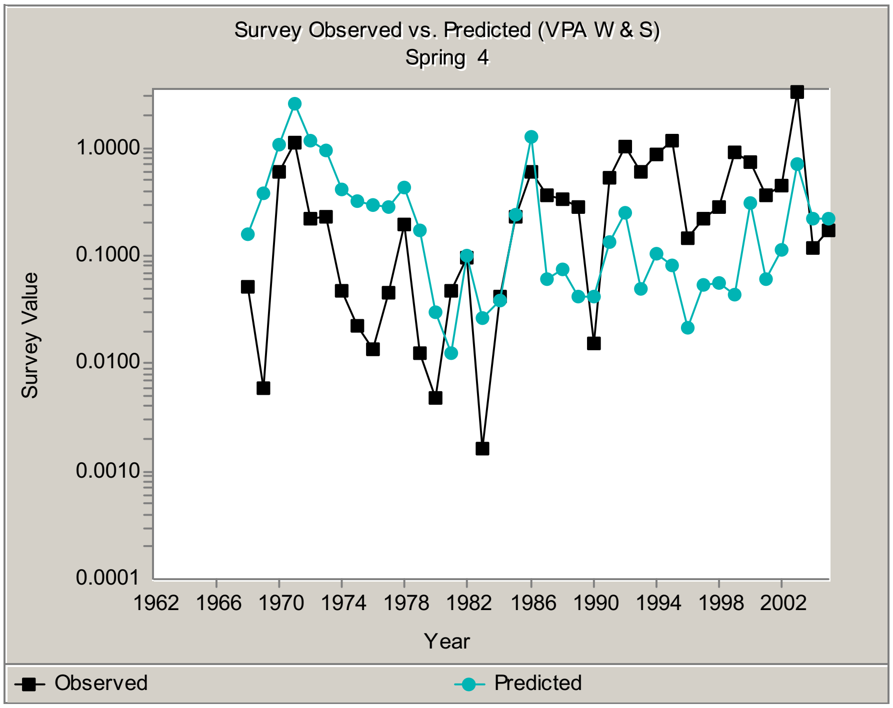

Figure 3 (APPENDIX B1). Spring survey observed vs. predicted series (age 4) for a VPA trial run with the winter and spring survey indices.

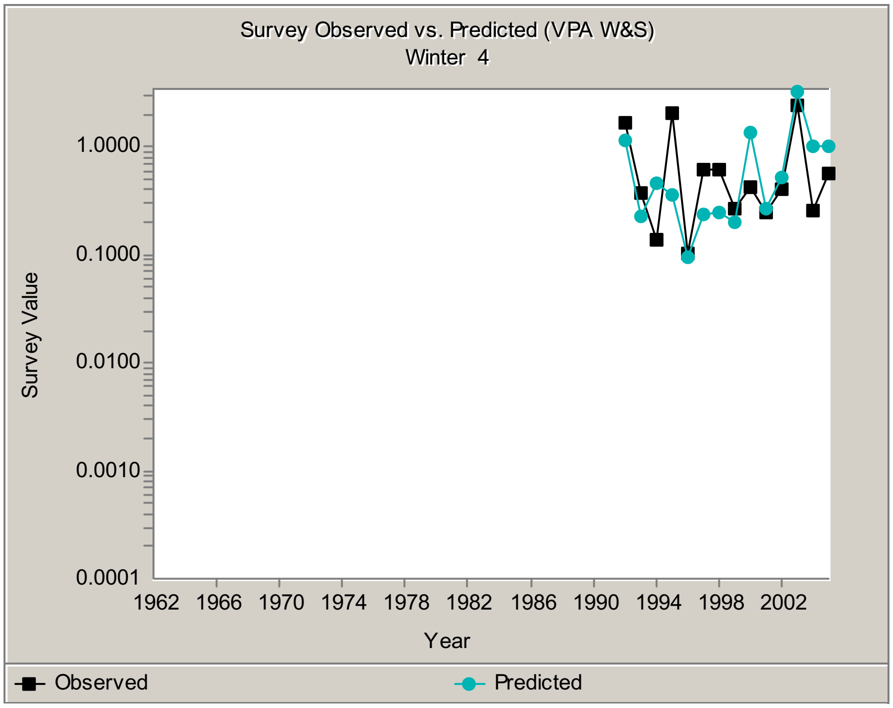

Figure 4 (APPENDIX B1). Winter survey observed vs. predicted series (age 4) for a VPA trial run with the winter and spring survey indices.

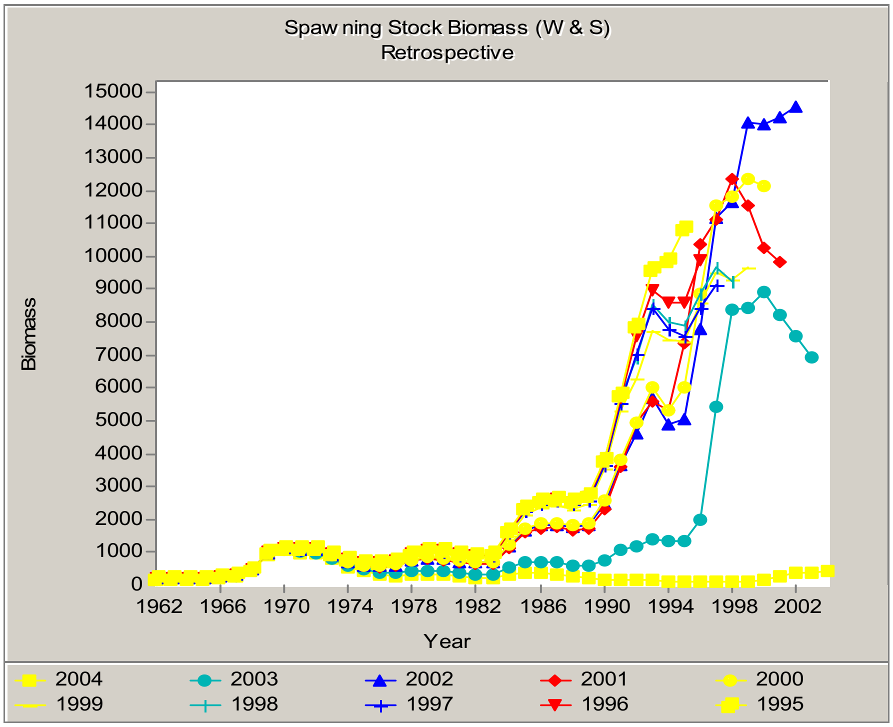

Figure 5 (APPENDIX B1). Retrospective pattern for SSB for a VPA trial run with the winter and spring survey indices.

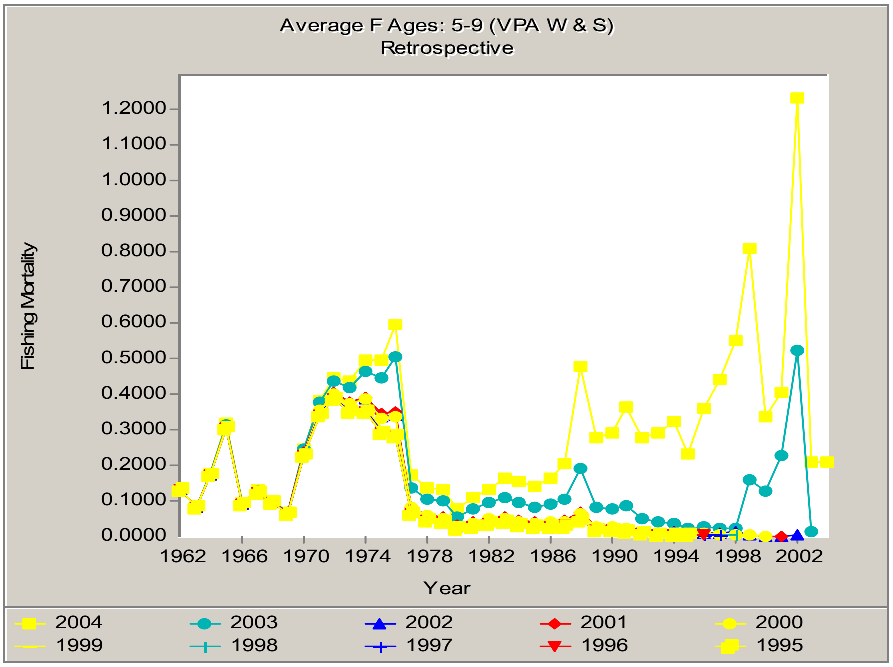

Figure 6 (APPENDIX B1). Retrospective pattern for SSB for a VPA trial run with the winter and spring survey indices.

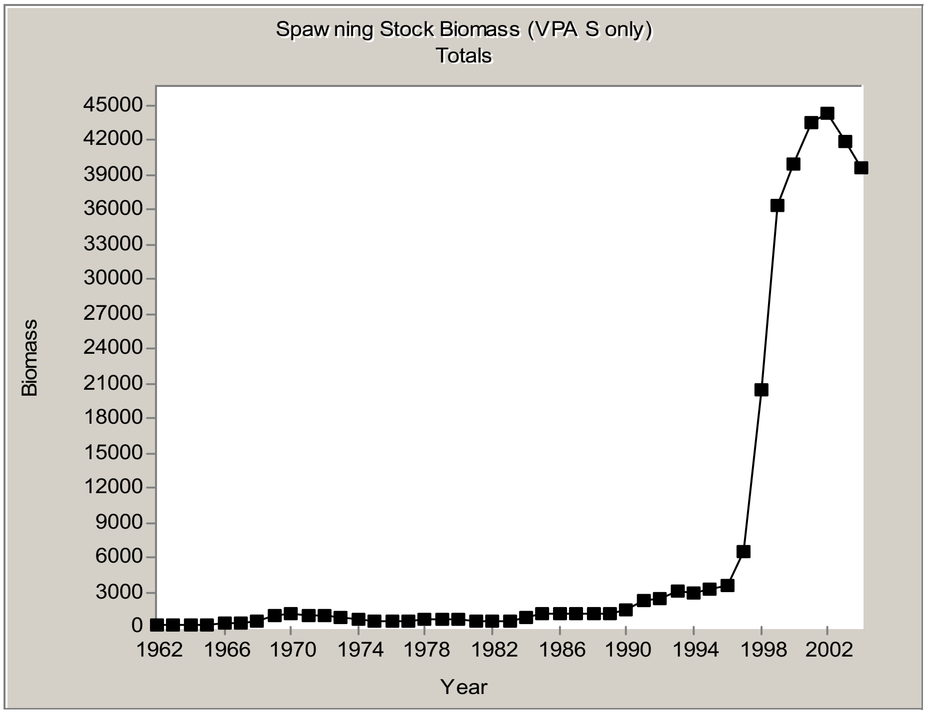

Figure 7 (APPENDIX B1). Spawning stock biomass for a VPA trial run with the spring survey indices.

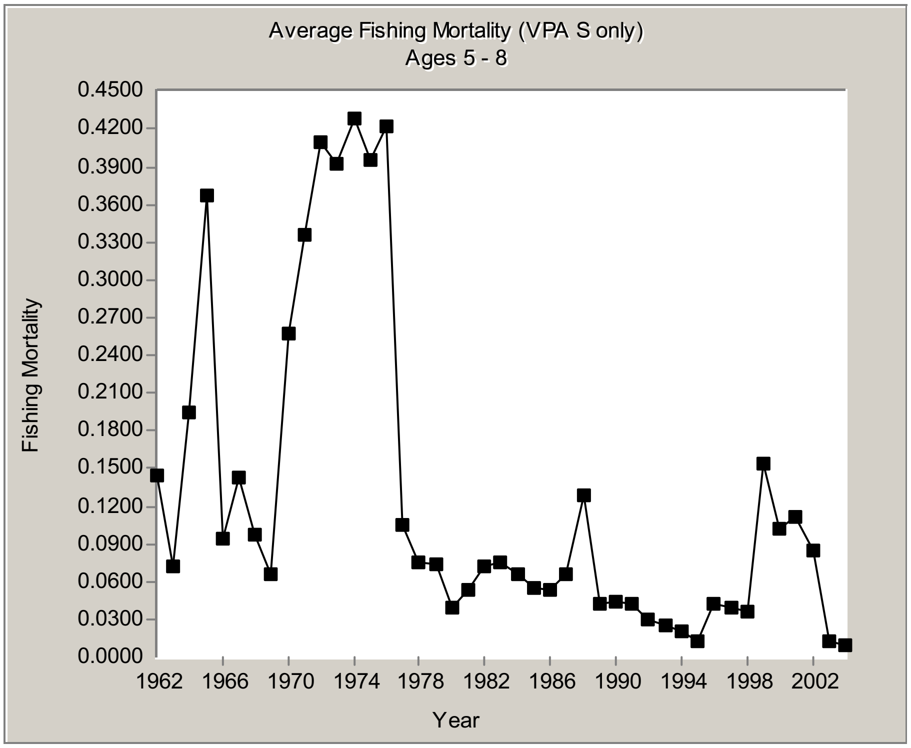

Figure 8 (APPENDIX B1). Fishing mortality for a VPA trial run with the spring survey indices.

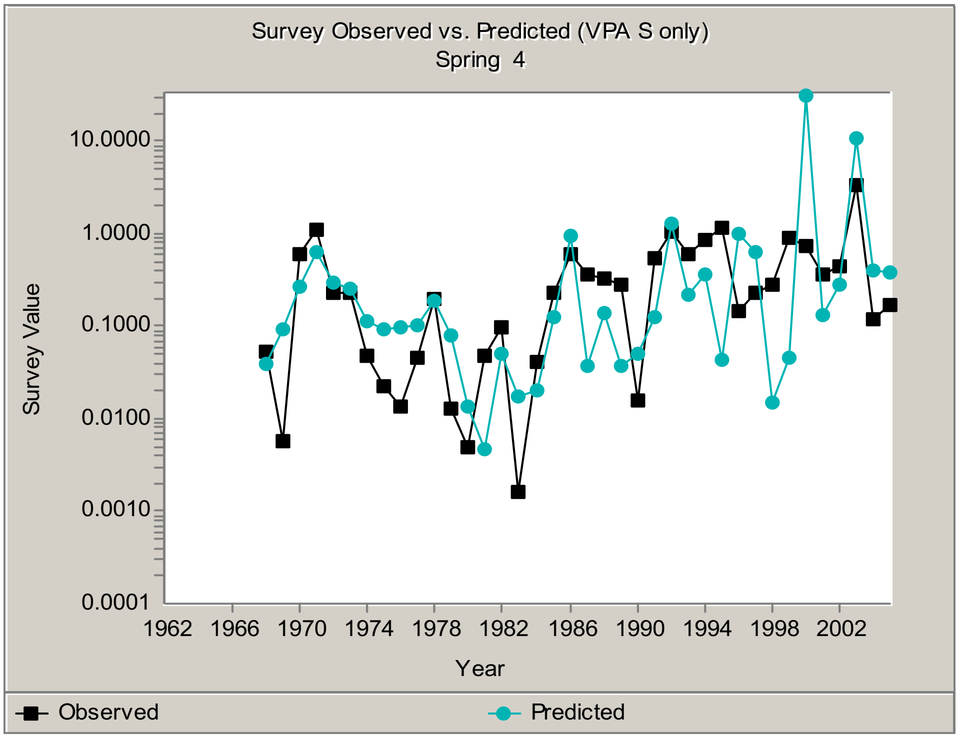

Figure 9 (APPENDIX B1). Spring survey observed vs. predicted series (1968-2004, age 4) for a VPA trial run with the spring survey indices.

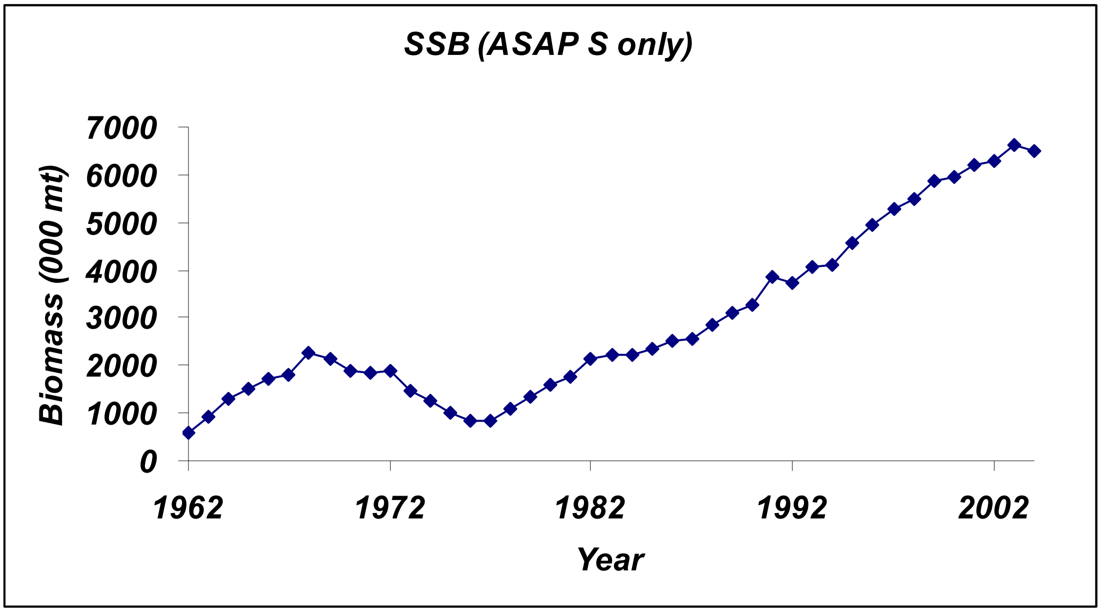

Figure 10 (APPENDIX B1). Spawning stock biomass for an ASAP trial run with the spring survey only.

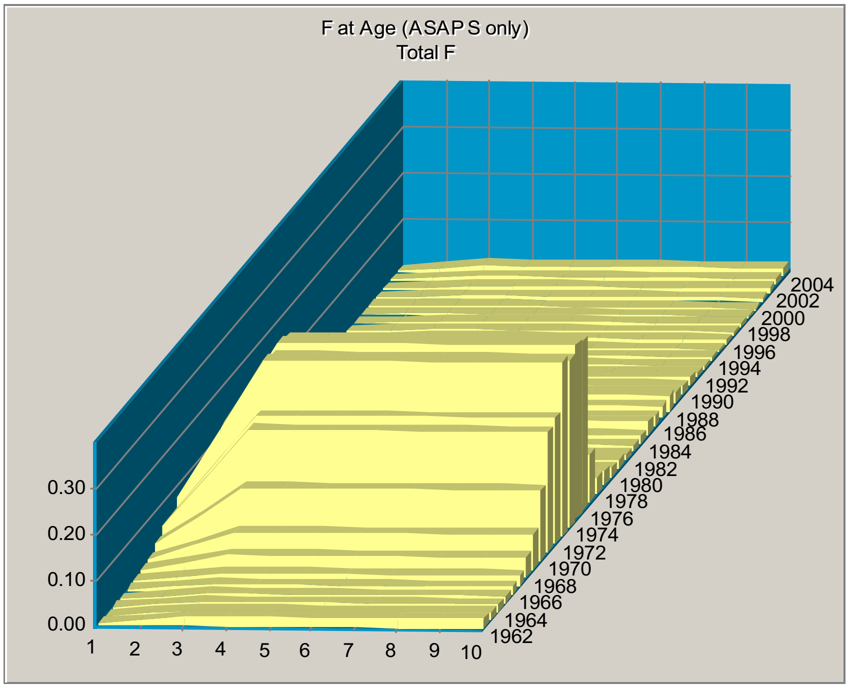

Figure 11 (APPENDIX B1). Fishing mortality by age and year for an ASAP trial run with the spring survey only.

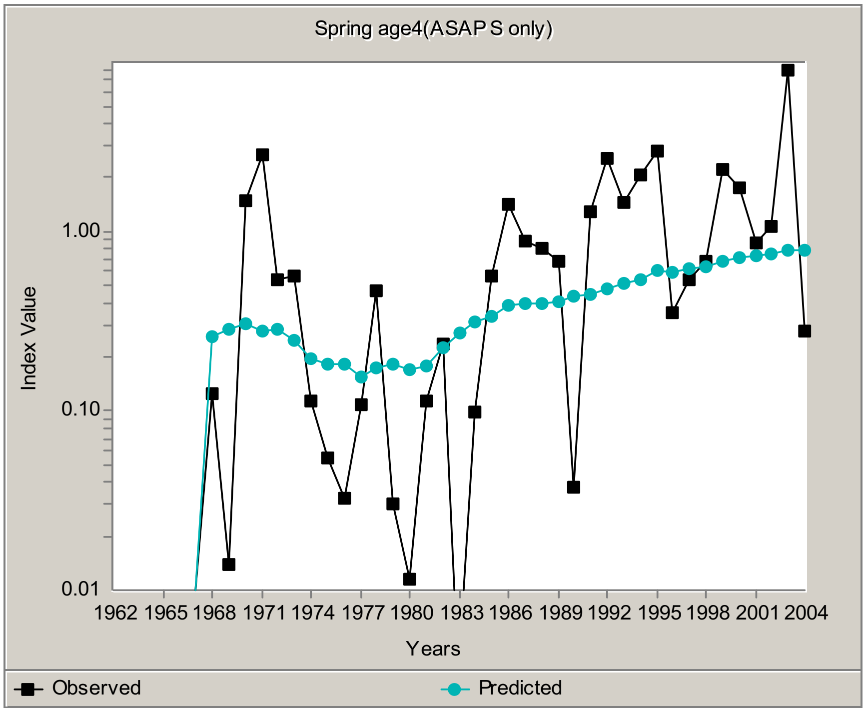

Figure 12 (APPENDIX B1). Spring survey observed vs. predicted series (1968-2004, age 4) for an ASAP trial run with the spring survey only.

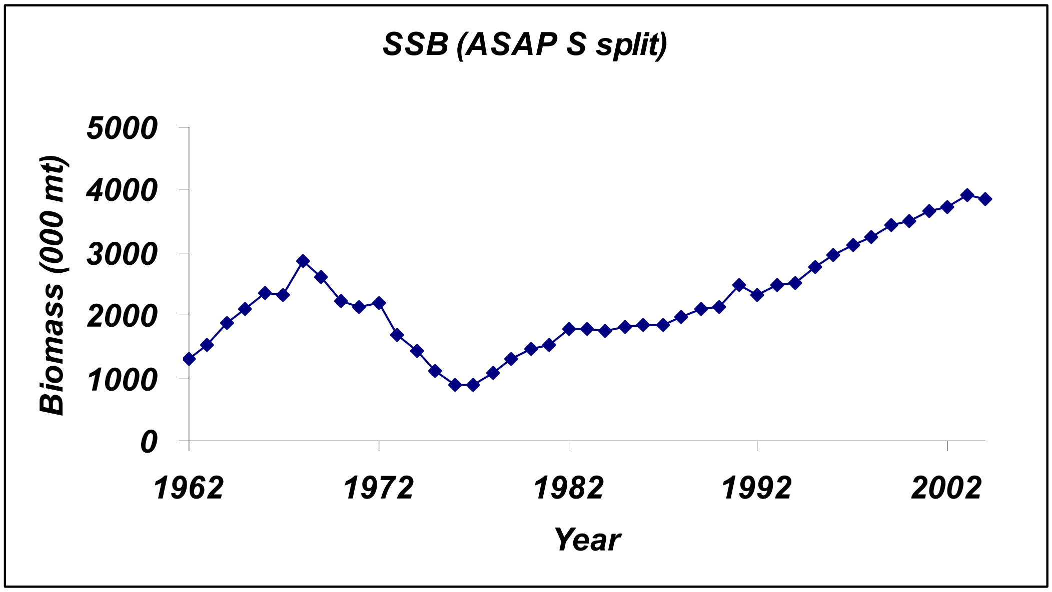

Figure 13 (APPENDIX B1). Spawning stock biomass for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

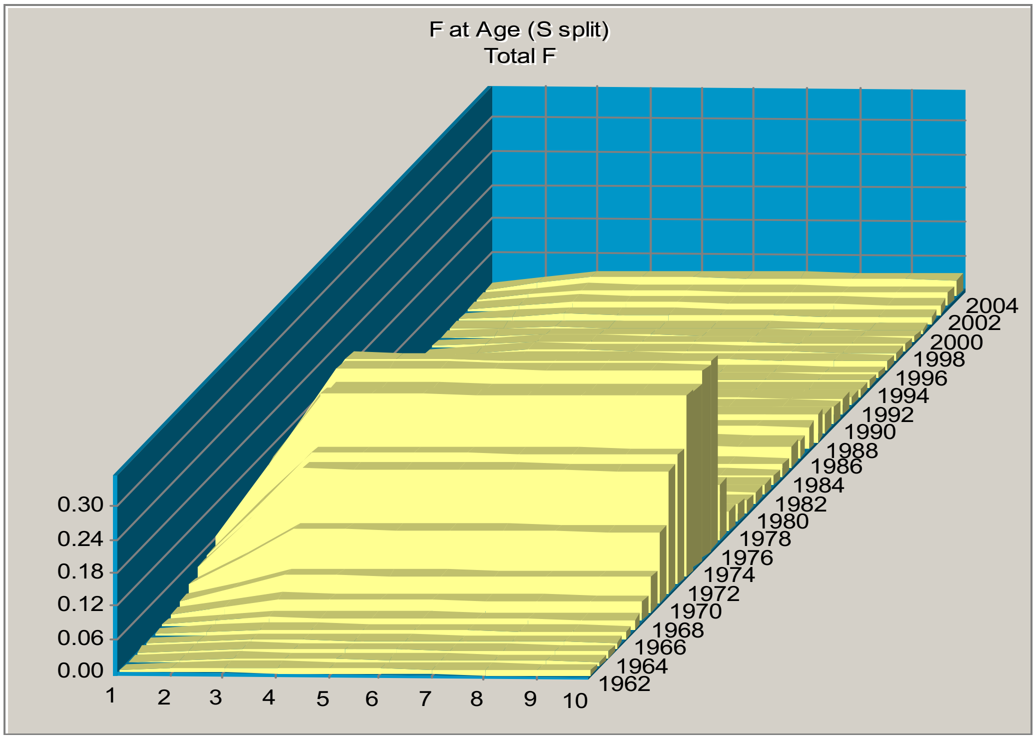

Figure 14 (APPENDIX B1). Fishing mortality by age and year for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

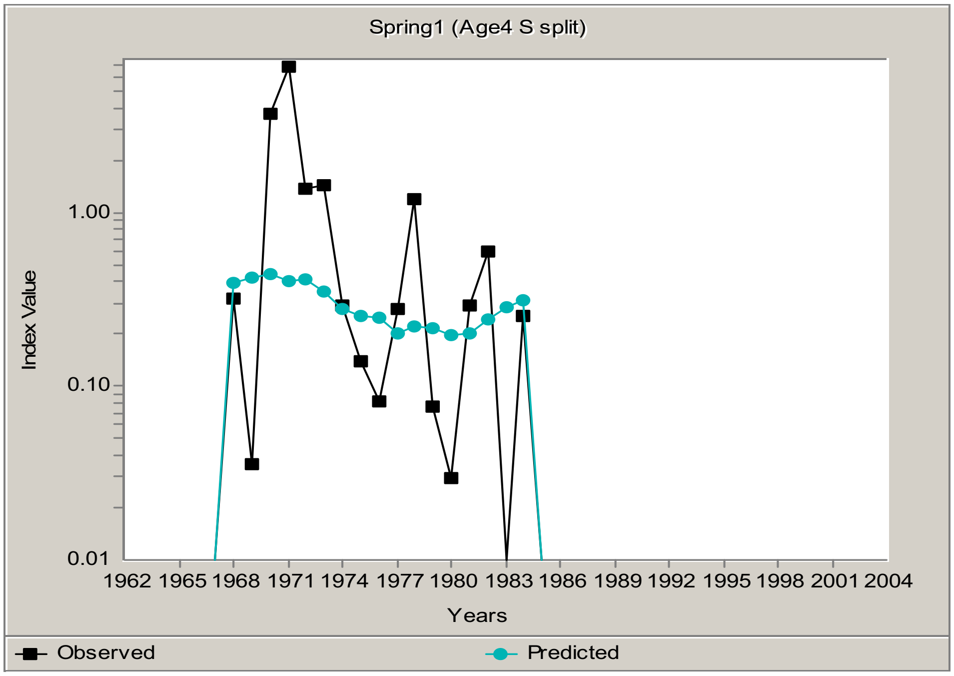

Figure 15 (APPENDIX B1). Spring survey observed vs. predicted series (1968-1984, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

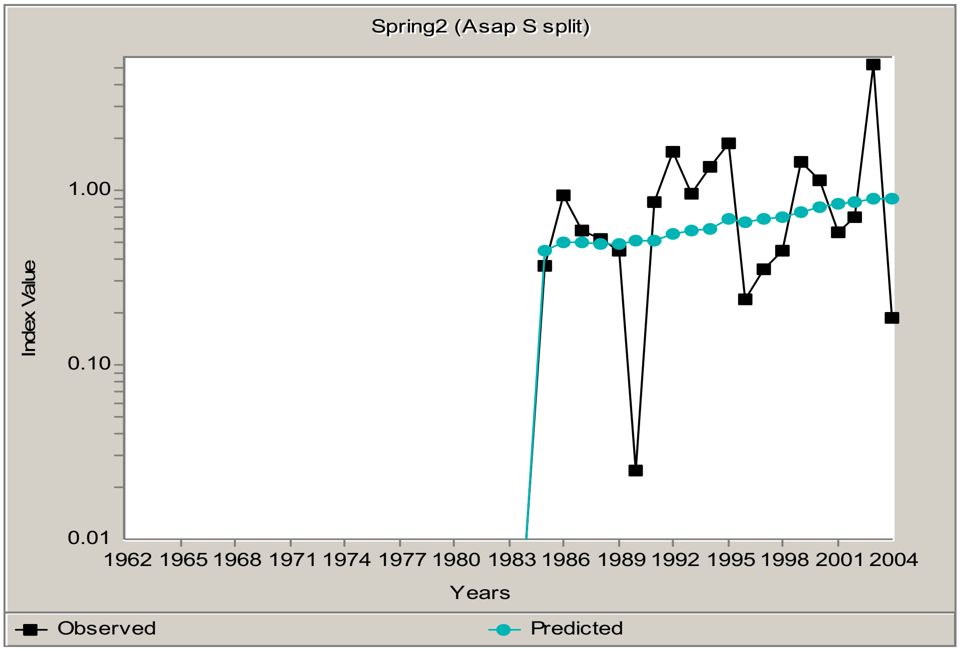

Figure 16 (APPENDIX B1). Spring survey observed vs. predicted series (1985-2004, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series.

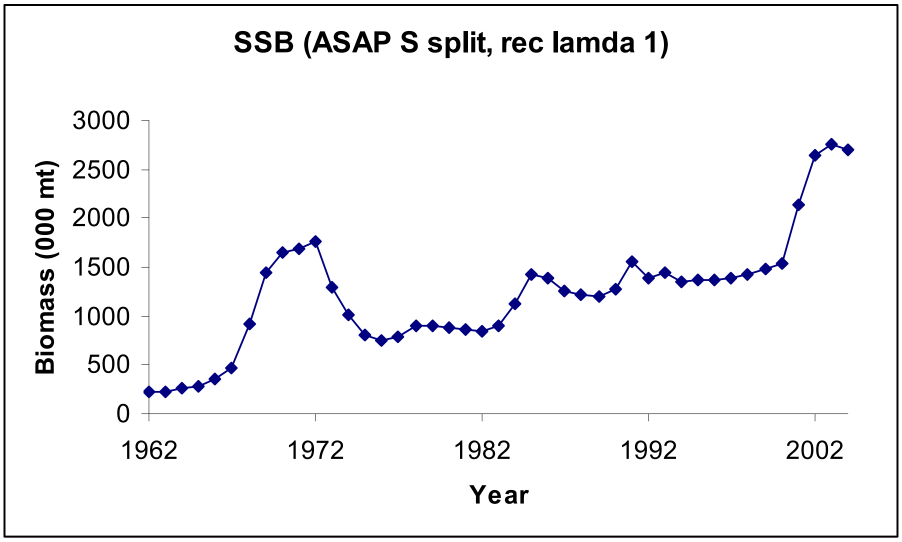

Figure 17 (APPENDIX B1). Spawning stock biomass for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

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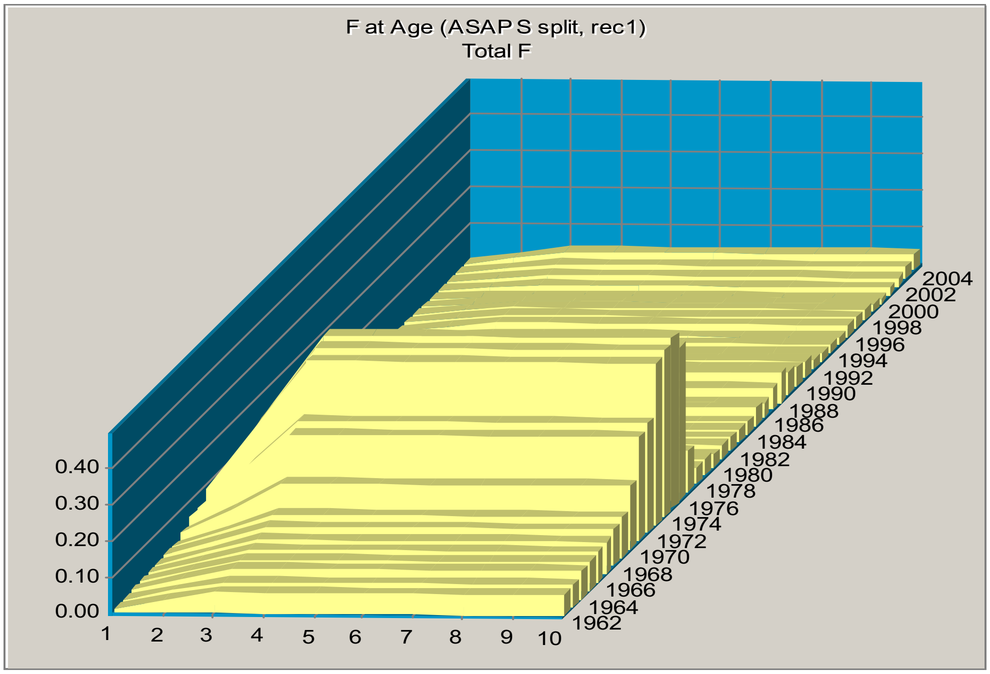

Figure 18 (APPENDIX B1). Fishing mortality for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

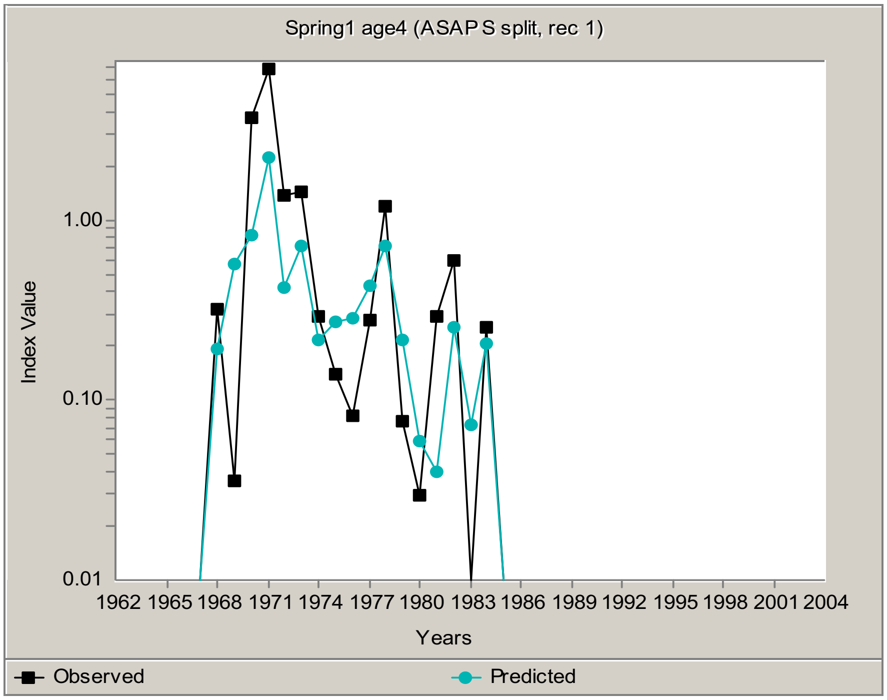

Figure 19 (APPENDIX B1). Spring survey observed vs. predicted series (1968-1984, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

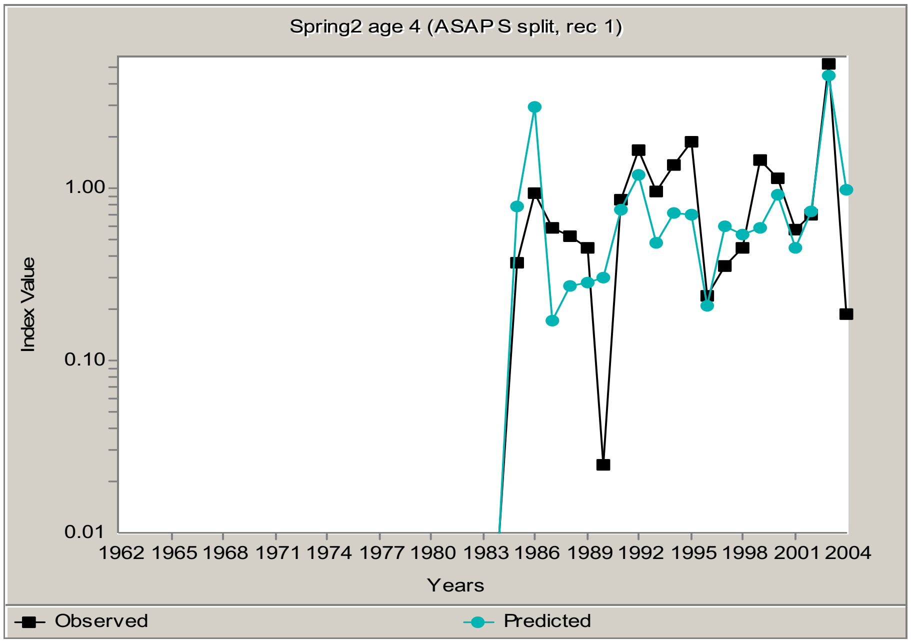

Figure 20 (APPENDIX B1). Spring survey observed vs. predicted series (1985-2004, age 4) for an ASAP trial run with the spring survey split into pre 1985 (1968-1984) and post 1985 (1985-2004) series and a B-H SR relationship with lambda = 1.

Appendix B2. Sensitivity Runs for Atlantic mackerel stock assessment.

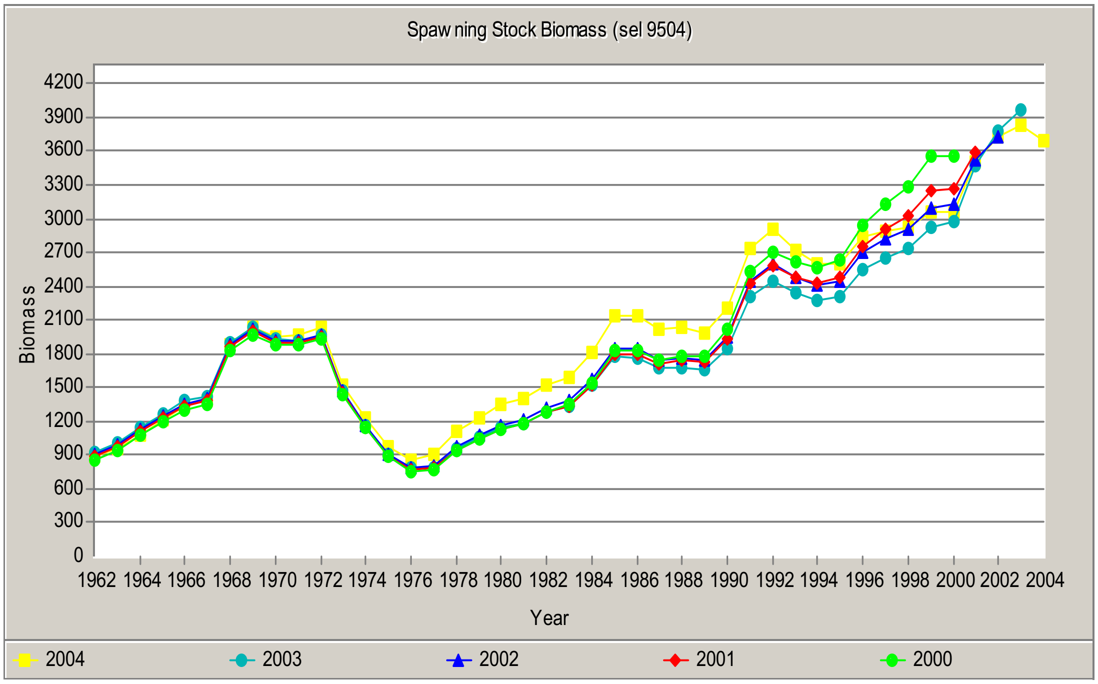

Figure 1 (APPENDIX B2). Retrospective pattern for SSB for the ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), ages aggregated to 7+, and estimated fishery selectivity during 1995-2004.

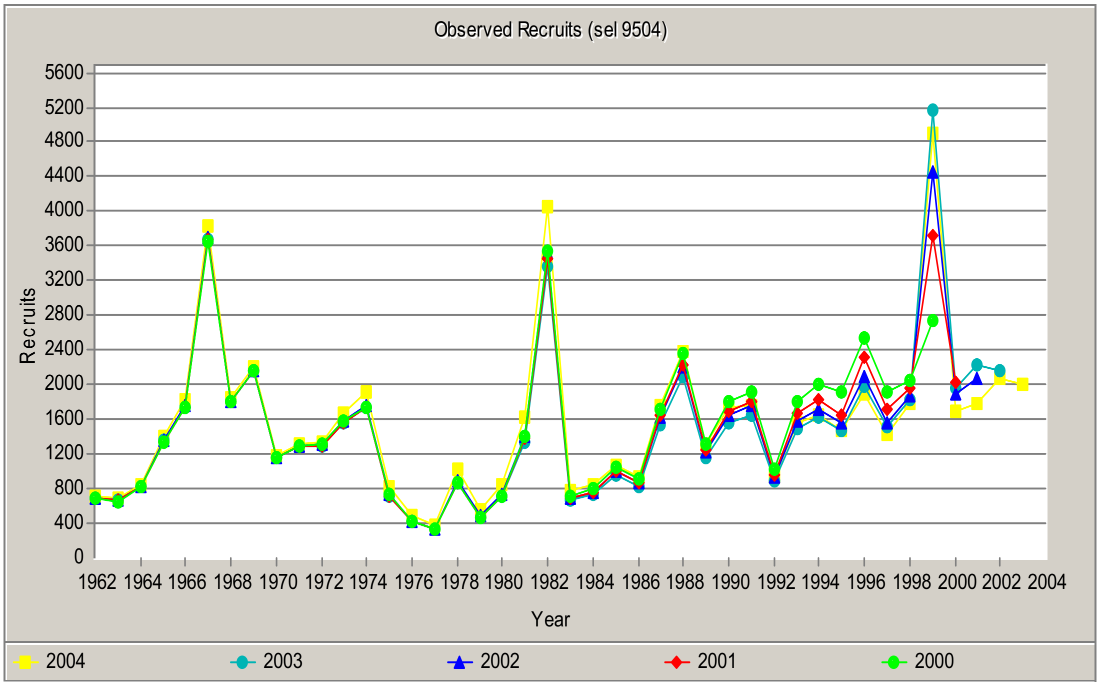

Figure 2 (APPENDIX B2). Retrospective pattern for recruitment for the ASAP model with the spring survey split in 1985, B-H SR model (lambda = 1), ages aggregated to 7+, and estimated fishery selectivity during 1995-2004.

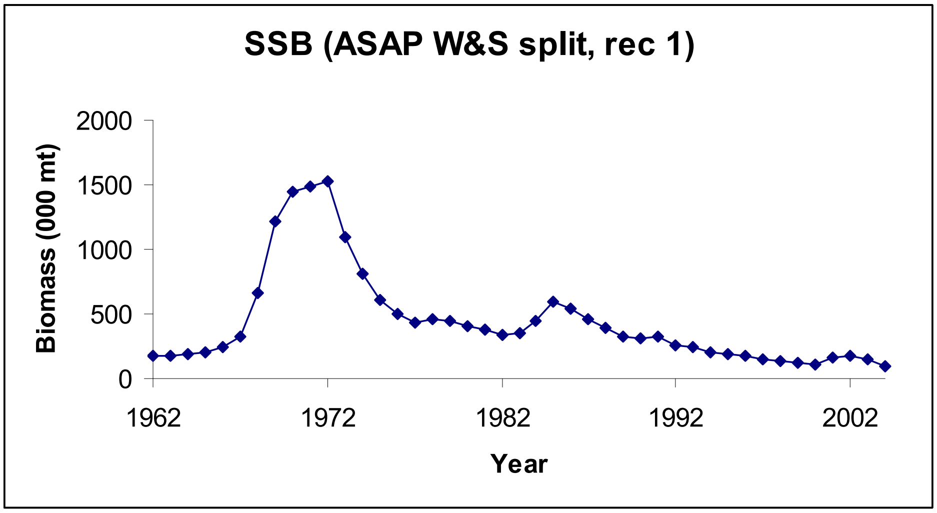

Figure 3 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on spawning stock biomass.

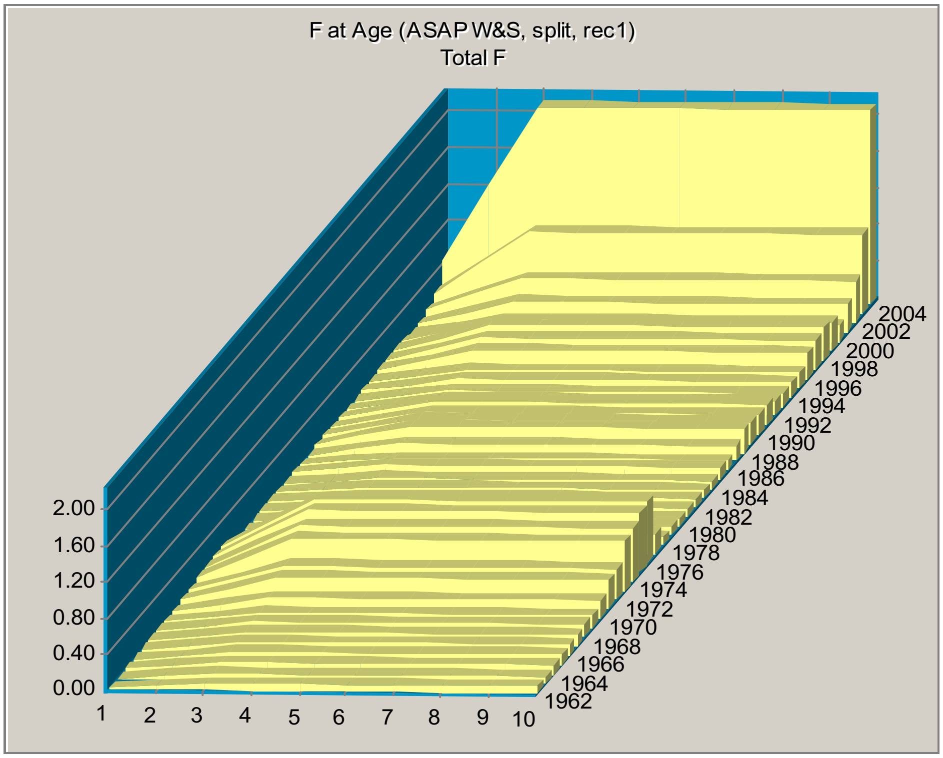

Figure 4 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on fishing mortality.

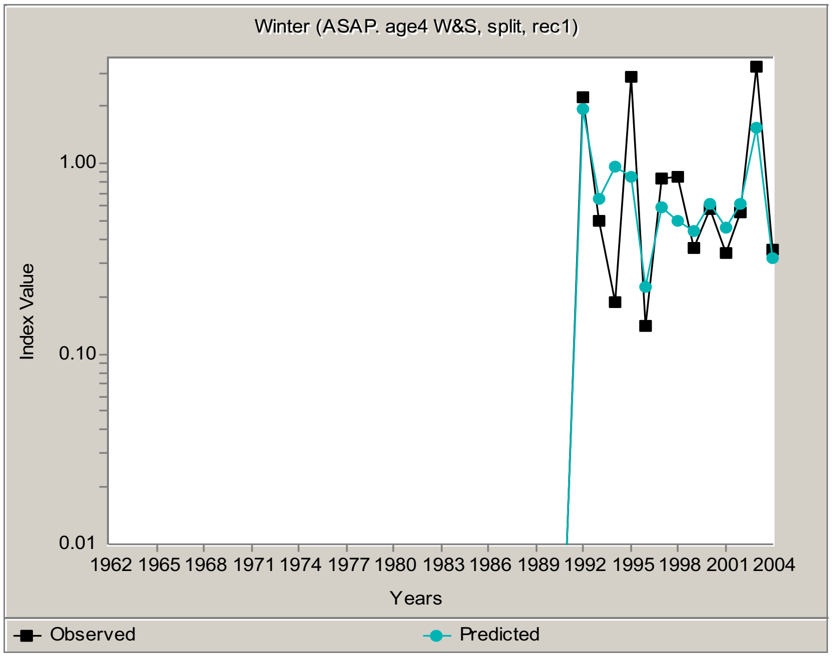

Figure 5 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on winter survey observed vs. predicted series.

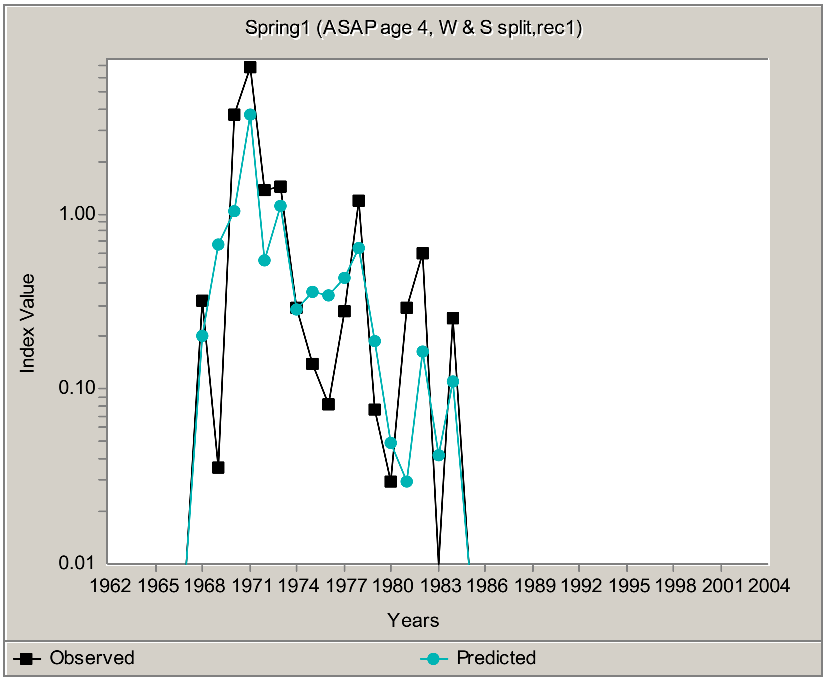

Figure 6 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on spring1 survey observed vs. predicted series.

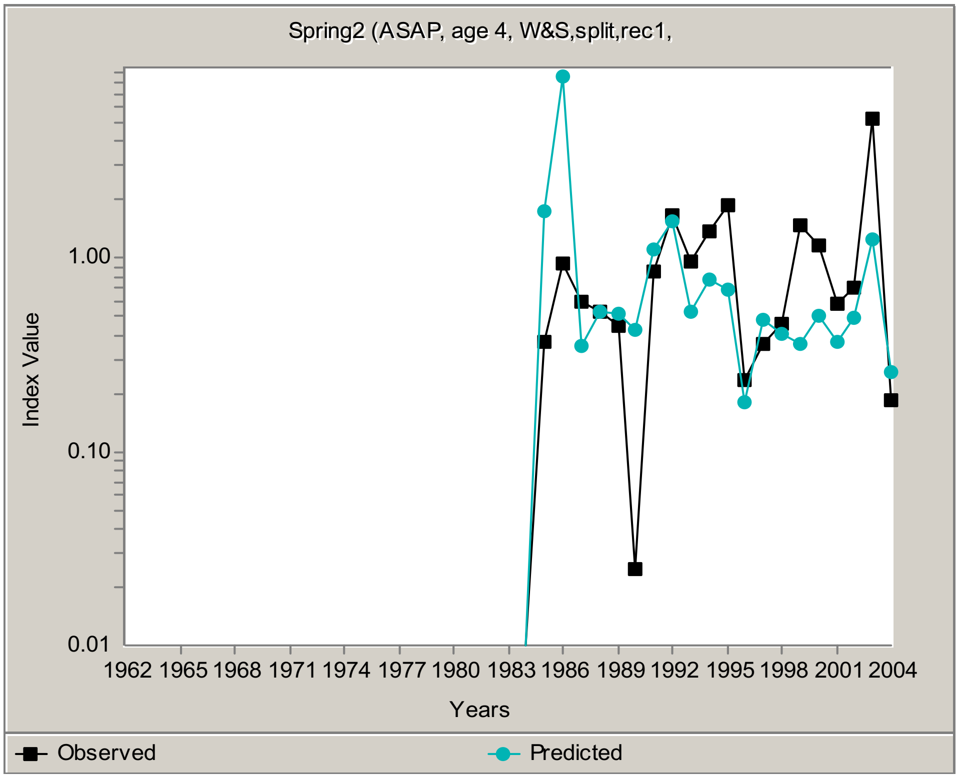

Figure 7 (APPENDIX B2). Sensitivity run to assess the effect of adding the NEFSC winter survey to the ASAP model, impact on spring2 survey observed vs. predicted series.

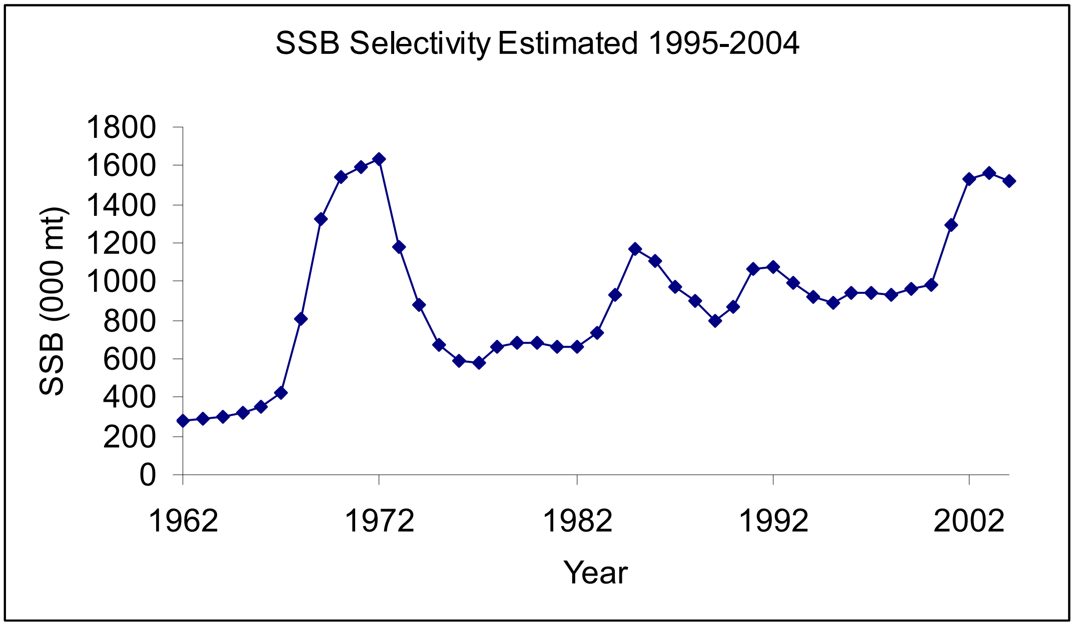

Figure 8 (APPENDIX B2). Results for SSB from a sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model.

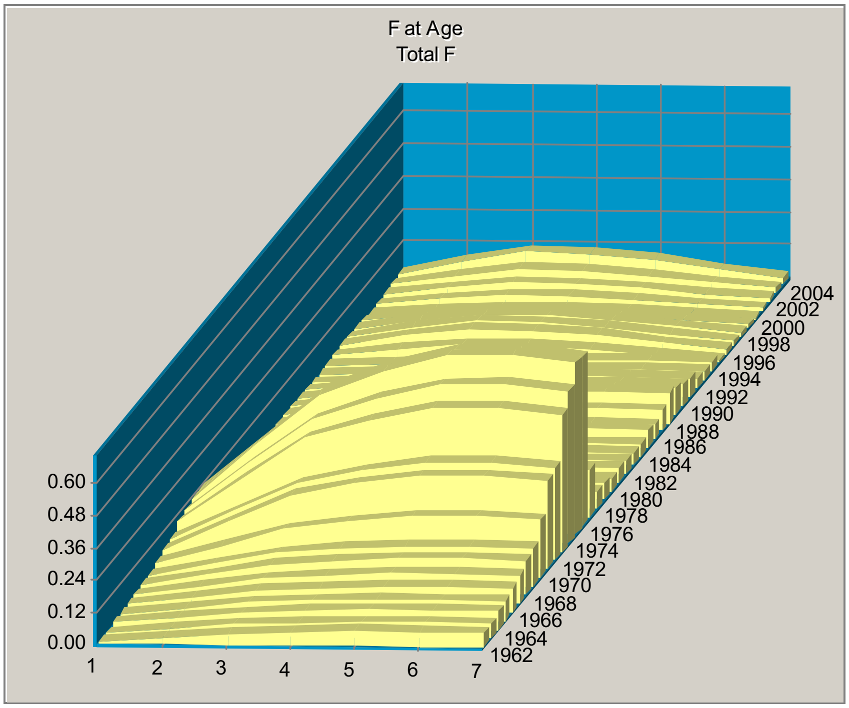

Figure 9 (APPENDIX B2).Results for fishing mortality from a sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model.

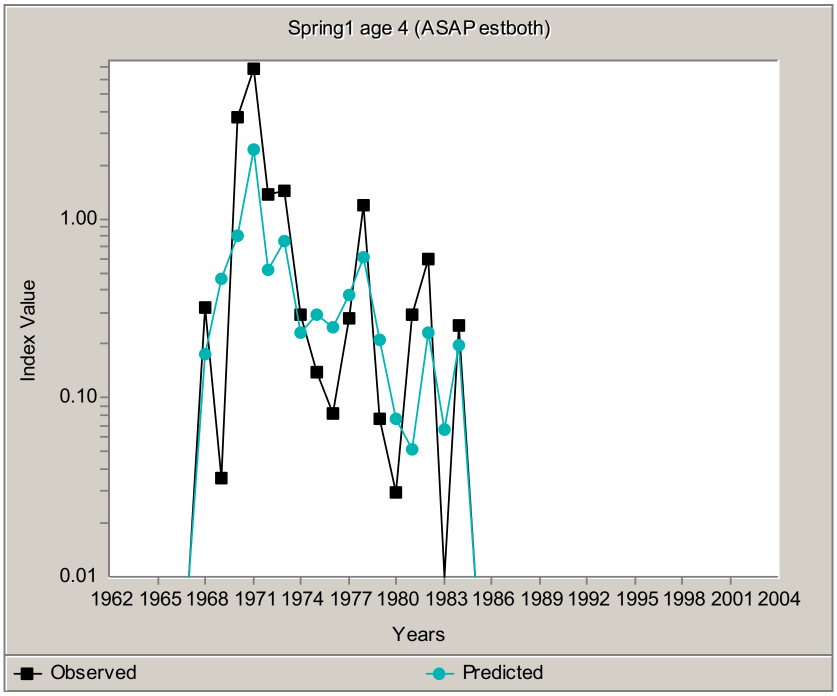

Figure 10 (APPENDIX B2). Sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model on spring1 survey observed vs. predicted series.

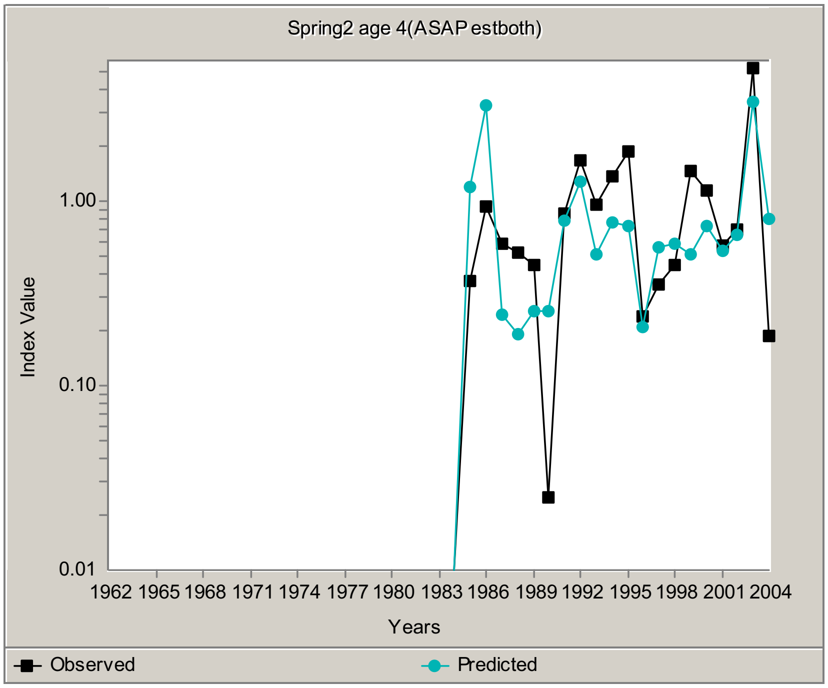

Figure 11 (APPENDIX B2). Sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model on spring2 survey observed vs. predicted series.

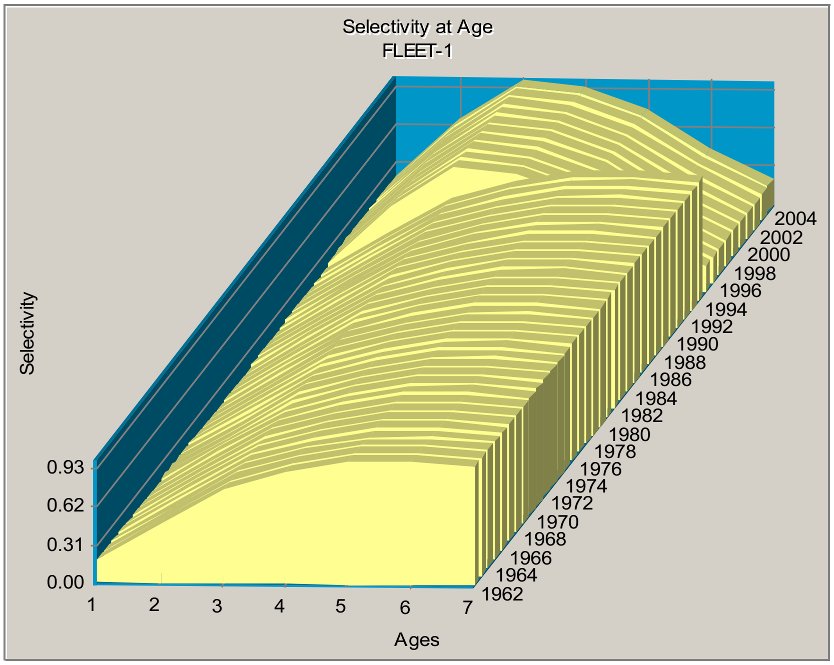

Figure 12 (APPENDIX B2). Sensitivity run to assess the effect of estimating fishery selectivity during 1962-1994 and 1995-2004 in the ASAP model on fishery selectivity.

APPENDIX B3: Rapporteur's Report from Mackerel Working Group Meeting

Concerns were raised regarding the lack of correspondence between the total landings from VTR and weighout data for 2004. Although some Atlantic mackerel may be going to bait markets without passing through dealers, industry representatives think 85-90% of landings pass through dealers, accounting for the vast bulk of landings. In Canada it is known that there is underreporting of catch going to the bait market, but they cannot quantify the magnitude, although it is not expected to be a major portion of the catch. There are no discard estimates but these catches are thought to be minor based on the gear required to catch mackerel in most years. However, as large year classes enter the fishery discarding of small fish may be an issue. The Working Group agreed that current catch estimates are reasonable.

The Working Group noted that although commercial landings increased in 2004 the number of length and age samples collected decreased. The 2004 sampling was inadequate and sampling should increase in future years to ensure the estimated catch at age is representative of the actual landings.

The relative lack of old fish in both the commercial catch and the surveys caused concern. Several possible explanations were discussed. The most likely explanations for the commercial catch was either a shift in location of the fishery to more inshore waters where older fish are less available, a shift in the location of fish due to environmental conditions, or insufficient sampling of the catch to detect the old fish amongst the more numerous younger fish. It was noted that the surveys have never caught large numbers of old mackerel but it could not be easily explained why the old fish are not currently seen by the survey if they are present in the area. The alternative explanation of a high fishing mortality rate does not agree with the recent low catches compared to historical catches. The Canadian fishery is targeting the large 1999 year class, which could explain the lack of old fish in that portion of the landings.

Retransformation of the spring index was discussed in detail. The technical procedure was described but an apparent inconsistency between the regular scale and retransformed data caused concern, specifically the change in direction from 2003 to 2004 between the regular and retransformed plots. It was explained that single large tows can lead to this apparent inconsistency. Since the retransformed data is then split into age groups, and the age samples from the early part of the time series are not available electronically, it is currently not possible to compute untransformed indices for the entire time series.

The Canadians have observed large changes in migration paths, timing of arrival and departure, distribution, etc. in recent years. This has made Canadian surveys difficult to use because their surveys are not measuring changes in abundance but rather changes in availability. They are continuing to explore development of indices, but the indices are not ready yet.

The Working Group agreed that since it is not possible currently to quantify the impact of consumption by predators on the natural mortality rate, the use of constant M in modeling is justified.

The Working Group agreed that the VPA models did not provide reasonable estimates for this stock and so was not used as a tool for classifying current stock status. The added structure in the

ASAP model allowed development of a Base Case analysis and a number of sensitivity runs to evaluate current stock status. The Base Case ASAP run has good fits to the indices and catch at age data, but exhibits a retrospective pattern. The Working Group concluded that it was preferable to keep this model even though it has a retrospective pattern because the approach that reduced the retrospective pattern, allowing a dome in recent years for the commercial fishery, could not be sufficiently justified. The Working Group agreed that without strong evidence for a domed pattern in recent years, the default of an asymptotic pattern for all years was most appropriate for this stock. The uncertainty in the recent SSB estimates was relatively high and encompassed most sensitivity runs.