Stock Assessment of Large Coastal Sharks in the U.S. Atlantic and Gulf of Mexico

by

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SUMMARY

The last stock assessment of large coastal sharks was conducted in 1998. The main conclusions of the 1998 Report of the Shark Evaluation Workshop were that recent (for 1996 and 1997) catch rate data continued to show inconsistent trends and thus longer time series of catch rate estimates would be required to detect changes since the implementation of management measures in 1993. Bayesian surplus production model analyses estimated that the 1998 stock size of the large coastal complex, sandbar, and blacktip shark was at 30-36%, 58-70%, and 44-50% of the MSY level, respectively. Following a peer review process, a sensitivity analysis of the results of the 1998 stock assessment to new data and model formulations concluded that, with a few exceptions, the results were not very sensitive to the majority of changes introduced. However, it was noted that the results for blacktip were sensitive to the importance function used and especially the method used to weight the CPUE indices.

With the addition of four more years of catch estimates, new biological data, and a number of fishery-independent catch rate series, as well as extended fishery-dependent catch rate series, there was sufficient information to conduct a new stock assessment of the large coastal shark complex, sandbar, and blacktip sharks. The objective of this stock assessment was thus to provide an update on the estimated status of large coastal shark stocks and project their future abundance under a variety of future catch levels in waters off the U.S. Atlantic and Gulf of Mexico coasts.

Additionally, this report addresses criticisms and recommendations contained in the CIE and NRC reviews by including extensive sensitivity analyses, using new models that incorporate age structure implicitly and explicitly, and considering also a previously used maximum likelihood estimation model.

Several stock assessment models were used to evaluate the status of the large coastal shark complex, sandbar, and blacktip shark using Bayesian and maximum likelihood (frequentist) statistical techniques. First, a nonequilibrium Schaefer biomass dynamic model was used to model the population dynamics of these three groupings using the SIR algorithm (Bayesian SPM) and several weighting schemes. Second, a nonequilibrium Schaefer state-space surplus production model (SSSPM) was also used to describe the population dynamics of these three groupings using a Markov Chain Monte Carlo (MCMC) method for numerical integration. Third, a lagged recruitment, survival, and growth (SSLRSG) state-space model was also used to model the dynamics of the three groupings. This model takes into account the lag between birth and subsequent recruitment to the adult stock, and thus some of the age structure effects on stock dynamics. In the second and third approaches a state-space model accounts for both process error and observation error in a unified analytical framework that uses Gibbs sampling to draw from the joint posterior distribution. Fourth, the so-called maximum likelihood estimation model developed by Parrack (1990) was also applied to the large coastal shark complex (MLE). And finally, a fully age-structured, state-space population dynamics model (ASPM) that allows the simultaneous use of Bayesian and frequentist statistical techniques for parameter estimation was used for sandbar and blacktip shark status evaluations.

Several catch and catch rate scenarios were considered in modeling. One scenario (updated) consisted of updating the catch estimates used in the 1998 SEW up to 1997, and adding estimated catches for 1998-2001. The baseline scenario differed from the updated scenario by including estimates of discards from the menhaden fishery and estimates of Mexican catches, and extended estimates of bottom longline discards, commercial landings, and recreational catches back to 1981 (for sandbar and blacktip shark), largely based on information provided by participants at the 2002 SEW workshop. The baseline scenario catches are considered to be more inclusive of the total catch since 1981, but have less supporting documentation for the estimates of catch, for some sectors, than those used in the update scenario. An alternative catch scenario for the large coastal shark complex attempted to reconstruct historical catches and was based largely on information provided by individuals familiar with shark fishing in attendance at the 2002 SEW, but which is difficult to fully document. The CPUE series used in the updated scenario were series previously used in the 1998 SEW, extended to include up to 2001 if available. They included 19 series for the large coastal shark complex, 10 series for sandbar shark, and 8 series for blacktip shark. The CPUE series used in the baseline scenario included those in the updated scenario and new series that became available since the 1998 SEW was conducted or that had not been used for that assessment, and were deemed appropriate for use in the baseline analyses.

For the large coastal shark complex, the Driftnet observer series was added to the baseline scenario, which with this addition, consisted of a total of 20 CPUE series. For sandbar and blacktip shark, the baseline scenario included the same series as those used in the updated scenario. The same CPUE series used for the baseline scenario were also used in the alternative catch scenario for the large coastal shark complex. Sensitivity analyses of the effect of considering only fishery-dependent or fishery-independent series, adding (or removing) specific series, and altering the alternative catch series were also conducted. Age-specific fishery-dependent and fishery-independent CPUE series were added in the age-structured analyses for sandbar and blacktip sharks.

For the large coastal shark complex, the series starting in the mid- or late-1970's (Virginia LL, Crooke LL, and Port Salerno) showed a decreasing trend until the early 1990's, but most of the series spanning 1993 onwards showed evidence of increasing tendency, although there is little indication of trend in the most recent catch rate patterns (1998-2001). For sandbar shark, the series starting in the mid-1970's (Virginia LL), early 1980's (early Rec), or mid-1980's (LPS) also showed a decreasing trend until the early 1990's, but most of the series spanning 1993 onwards also showed generally increasing trends, followed by a combination of mostly flat or slightly increasing trends in recent years (1998-2001). For blacktip shark, the only series starting in the early 1980's (early Rec) showed no clear trend, and most of the series spanning 1993 onwards did not show a clear trend either, with the exception of the BLL Logs ST series, which increased over time. In recent years (1998- 2001), both slightly decreasing and increasing trends could be observed in the available catch rate patterns. Age-specific catch rate time-series for sandbar shark showed decreasing trends overall for the Virginia LL series for all juvenile ages, with the series typically starting high in the early 1980's, decreasing markedly in the early 1990's, and increasing or stabilizing since the mid-1990's. The early Rec series for juveniles also showed a decreasing trend from the early 1980's to the mid-1990's, followed by an increase in the late Rec series from 1993 onward. The SCLL recent series also showed a slightly increasing trend since the mid-1990's for juveniles. The two series available for adults only (Virginia LL and PLL) both showed increasing trends since the mid-1990's, although the Virginia LL generally decreased when considering the whole time period. Series that included all age groups showed conflicting trends, with some decreasing and some increasing. Age-specific series for blacktip shark showed a stationary or increasing trend since the mid-1990's for age-0 individuals (2 series), a decreasing or unclear pattern for juveniles ages 0-5 (5 series), and a slightly increasing trend for adults (ages 6+; 1 series). Series that included all age groups showed conflicting trends, with three series increasing and two decreasing.

Results for the large coastal shark complex were sensitive to the index-weighting scheme used, with several methods indicating that some reduction in the fishing level could be needed to stabilize or increase the overall complex, but other models applied indicating that the fishing level in 2001 was sustainable. The form of the surplus production model (state space vs. non-state-space), the population dynamics model (surplus production vs. simplified delay-difference model), and the method of numerical integration (SIR vs. MCMC) also affected results, but tended to support the conclusion that some reduction in fishing could be needed to stabilize or increase the complex. The catch series considered (updated, baseline, alternative) had a small effect on results when using the equal weighting method, but changed the sign of the predictions of stock status when using the inverse variance weighting method. The CPUE series considered had a profound effect on results. Using only fishery-dependent series in the Bayesian SPM model fitting predicted a high level of depletion and indicated further decreases in catches could be needed to achieve recovery, whereas considering only fishery-independent series predicted that the present level of removals is likely sustainable and that even a 20% increase in catches might still result in abundance being above MSY level in 10 years. These results are directly related to the trend seen in the two sets of CPUE series for the large coastal shark complex, which shows a general increase from the mid-1990's in the fishery-independent indices. Results obtained with the Bayesian SPM appeared to have converged according to the CV diagnostic used, but convergence diagnostics for the SSSPM and SSLRSG models were equivocal, although the model fits to the CPUE series were generally good.

In general, the predictions of the large coastal complex resource status from the SSLRSG models were closer to those from the Bayesian SPM model than those from the SSSPM models. In all, results for the large coastal shark complex show that the status of the resource has improved since 1998. However, summarized results averaged over the models fit indicated that overfishing could still be occurring and the resource may be overfished. Averaged across the models considered plausible, a reduction in catch of 50% of the 2000 catch level could be required for the biomass to reach MSY in 10 years. These results could be considered contradictory with some of the species-specific results. However, the catch and catch rate series used in the large coastal complex represent a broad range of species, some of which are in apparent decline while others show signs of either increase or relative stability.

Results for sandbar shark were rather insensitive to the catch series and weighting method used, and indicated that abundance levels are near or slightly above MSY level. The closest agreement in results was between the Bayesian SPM and the SSLRSG models, which also supported the conclusion that the resource is close to MSY levels. However, the addition of the LPS fishery-dependent CPUE series in the analysis, which showed a decreasing trend, reversed the sign of the predictions, indicating that current resource abundance was below that producing MSY and current fishing mortality well above that producing MSY. Considering only fishery-independent series had little effect on results when using equal weighting, but resulted in more pessimistic predictions when using inverse variance weighting of indices. Although CV diagnostic values were higher than those for the large coastal shark complex, results obtained with the Bayesian SPM appeared to have converged. Convergence diagnostics for the SSSPM and SSLRSG models were also equivocal, but the model fits to the CPUE series were generally good. Predictions of resource status from the SSLRSG models were also closer to those from the Bayesian SPM model than those from the SSSPM models.

Results for sandbar shark were also obtained using the MLE and ASPM models. The MLE model estimated values of m, the parameter that represents the net annual change resulting from all inputs and outputs, very close to zero, which implied that the sandbar shark population could not be sustainably harvested, except at very low levels. Results obtained from the updated and baseline catch ASPM model applications were very different: the updated catch models indicated a high level of depletion, whereas the baseline models were much more optimistic, indicating that the resource is above MSY levels. However, all the ASPM scenarios that resulted in more optimistic results also estimated what was considered an unrealistically low value of historic catch, and thus should be considered cautiously.

Results for sandbar shark obtained with the five different models were contradictory. The MLE model application indicated that virtually no fishing could be sustainable and the results from the ASPM model predicted either extremely low values of historic fishing (and the most optimistic outcome) or very low values of current fishing (and the most pessimistic outcome), while results from the surplus production and simplified delay-difference models both indicated that the stock was near MSY level and no further reduction in fishing would likely be needed to maintain the stock at current levels. In all, results for sandbar shark showed that the status of the resource has improved since 1998. Summarized results, averaged over the models judged plausible, indicated that overfishing of the resource could be occurring, but that current biomass could be near or somewhat above that producing MSY.

Results for blacktip shark based on Bayesian SPM, SSSPM, and SSLRSG applications were also rather insensitive to the catch series and weighting method used, and generally indicated that recent abundance levels were above MSY and the current fishing level below that which would result in MSY. In these cases, the closest agreement in results was between the Bayesian SPM and one of the forms of the SSSPM model. Considering only fishery-dependent series affected results very little when using equal weighting, but resulted in a more pessimistic outlook when using inverse variance weighting of the indices, in which case indicating that current resource abundance would be close to MSY and the current fishing level slightly below F_{MSY}. However, there may have been convergence failure with the inverse variance weighting method. Considering only fishery-independent series had little effect on results, too. The CV diagnostic values were generally higher than those for the large coastal shark complex, but lower than those for sandbar shark. Convergence diagnostics for the SSSPM and SSLRSG models were again equivocal, but the model fits to the CPUE series were generally good, with the exception of the fit to the Shark observer series.

Results for blacktip shark were also obtained using the MLE and ASPM models. As for sandbar shark, the MLE model estimated values of *m* very close to zero, which implied that the blacktip shark population could not be sustainably harvested, except at very low levels. Results obtained from the updated and baseline ASPM models were not nearly as different as for sandbar shark. The estimate obtained with the model that used all the available catch rate information indicated that spawning stock biomass was a little under that which would produce MSY and current fishing mortality about 40% above that which would produce MSY. The baseline models yielded much more optimistic results, indicating that the resource was above MSY level and F below F_{MSY}. There were convergence problems when using only the fishery-dependent or fishery-independent indices with the baseline catch series models. Except for the predictions of the MLE model applications, which were judged to be implausible, results for blacktip shark were reasonably consistent in indicating that the resource is near and possibly somewhat above MSY levels. Resource status was thus estimated to have improved since 1998, and summarized results, averaged over plausible model predictions, indicated that resource status is at or above MSY levels, with only some of the age-structured models indicating that overfishing may be occurring. Over these results, no further reduction in blacktip catch is indicated as likely to be needed to maintain the stock at current levels, while some increase in TAC (20-50% of the 2000 catch) may be sustainable in the long term.

1. BACKGROUND

The original Fishery Management Plan (FMP) for Sharks of the Atlantic Ocean was first implemented on 26 April 1993 (NMFS 1993). Its main objectives were to: 1) prevent overfishing of shark resources; 2) encourage management of shark resources throughout their range; 3) establish a shark resource data collection, research, and monitoring program; and 4) increase the benefits from shark resources to the U.S. while reducing waste, consistent with the other objectives. During preparation of the FMP, it was determined that stocks of Atlantic large coastal sharks were below the level required to produce the maximum sustainable yield (MSY). In addition, the FMP called for an annual evaluation of information on shark landings, current stock condition, and information on which to base the total allowable catch (TAC).

After implementation of the FMP, NMFS convened three Shark Evaluation Workshops (SEW 1994 [NMFS 1994], SEW 1996 [NMFS 1996], and SEW 1998 [NMFS 1998]) as a mechanism to examine the available shark data and provide scientific advice to facilitate the evaluation of Atlantic shark resources. The 1998 Shark Evaluation Workshop was held at the Southeast Fisheries Science Center (SEFSC), Panama City Laboratory in June 1998. The document developed on the basis of the Workshop discussions reported that recent (for 1996 and 1997) catch rate data continued to show inconsistent trends and thus longer time series of catch rate estimates would be required to detect changes since the implementation of management measures in 1993. Bayesian surplus production model analyses estimated that the 1998 stock size of the large coastal complex, sandbar, and blacktip shark was at 30-36%, 58-70%, and 44-50% of the MSY level, respectively. Projections thus indicated that the large coastal shark complex might still require additional reductions in effective fishing mortality rate to ensure increase of the resource toward MSY. For blacktip shark, projections also indicated a need for additional reductions, but it was unclear whether reductions in the U.S. alone would achieve the intended goals. Projections for sandbar shark were more optimistic, suggesting that recent catches were closer to replacement levels. Based on life history analyses of the sandbar shark that showed that large juvenile and subadult individuals were likely to be the most sensitive stages in this species, it was also concluded that management approaches should be aimed at reducing fishing mortality in these stages. A minimum size limit of 140-cm fork length on the “sandbar-like” ridgeback sharks was identified as a possible strategy to reduce mortality in juvenile and subadult stages of sandbar sharks. Additionally, using similar life history arguments, a minimum size was also suggested for the “blacktip-like” non-ridgeback sharks as a strategy for reducing fishing mortality. However, in the case of blacktip, it was expected that a commercial minimum size might not achieve the desired results due to mortality of undersized blacktip sharks during normal fishing operations.

Fisheries affecting Atlantic shark resources are now being managed under the new Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks (HMS FMP), which was implemented in July 1999 (NMFS 1999). One of the main objectives of the HMS FMP is to prevent or end overfishing of Atlantic tunas, swordfish and sharks and adopt the precautionary approach to fisheries management. To achieve this and other objectives, after consideration of the 1998 SEW Report and other pertinent factors, NMFS implemented the following management measures (as well as others not listed below) for Atlantic shark resources under the HMS FMP: 1) reduce the recreational bag limit to 1 shark per vessel per trip, with a minimum size of 137 cm fork length for all sharks, and an additional 1 Atlantic sharpnose shark per person per trip; 2) prohibit possession of 19 species of sharks (Atlantic angel, basking, bigeye sand tiger, bigeye sixgill, bigeye thresher, bignose, Caribbean reef, Caribbean sharpnose, dusky, Galapagos, longfin mako, narrowtooth, night, sand tiger, sevengill, sixgill, smalltail, whale and white); and 3) limited access. Additionally, NMFS finalized the following measures in the HMS FMP: 1) reduce the annual commercial quota for large coastal sharks to 816 mt dw, apportioned between ridgeback (620 mt) and non-ridgeback (196 mt) sharks; 2) reduce the annual commercial quota for small coastal sharks to 359 mt dw; 3) reduce the annual commercial quota for pelagic sharks to 488 mt dw and establish a separate annual commercial quota of 92 mt dw for the porbeagle and an annual dead discard quota for blue sharks of 273 mt dw; and 4) establish a minimum size of 137 cm fork length for ridgeback sharks. However, due to a court order these measures were not implemented.

A Shark Evaluation Workshop was not reconvened in 1999, 2000, or 2001 because the amount of new information collected was insufficient to warrant a full new evaluation. Following the results of a peer review per a court-ordered settlement agreement, a sensitivity analysis of the results of the 1998 stock assessment to new data and model formulations was conducted (Cortes 2002a). The main conclusions were that, with a few exceptions, the results generally were not very sensitive to the majority of changes introduced. However, it was noted that the results for blacktip shark were sensitive to the importance function used and especially to the method used to weight the CPUE indices.

With the addition of four more years of catch estimates, new biological data, and a number of fishery-independent catch rate series, as well as extended fishery-dependent catch rate series, there was sufficient information to conduct a new stock assessment of the large coastal shark complex, sandbar, and blacktip sharks. The present document is an assessment of resource status and projection of future abundance for the large coastal shark complex, sandbar, and blacktip sharks. Most of the information used for this assessment was presented in the Meeting Report of the 2002 Shark Stock Evaluation Workshop (NMFS 2002) held in the SEFSC Panama City Laboratory in June 2002 and in the 40 documents that were presented at that workshop. Therefore, more detailed information on catches, catch rates, biological parameters, and assessment methods can be found in NMFS (2002) and the 40 documents cited therein. This report also addresses criticisms and recommendations contained in the CIE and NRC reviews, some of which had been previously addressed in the sensitivity analysis of the 1998 LCS SEW results to new data and model formulations (Cortes 2002a) and in the assessment of small coastal sharks in the U.S. Atlantic and Gulf of Mexico (Cortes 2002b). In addition to extensive sensitivity analyses, this document addresses specific issues contained in the reviews by using a fully age-structured model and revisiting a previously used maximum likelihood estimation model developed by Parrack (1990).

Sensitivity trials and model formulations undertaken in the present stock assessment include:

- Changes in the catch series (updated, baseline, alternative catch, and modified alternative catch scenarios)
- Changes in the CPUE time series (considering certain sets only)
- Changes in prior distributions (were already investigated in Cortes [2002a])
- Changes in the form of the Bayesian surplus production assessment model (state-space vs. non state-space)
- Changes in the importance function used for Bayesian estimation (multivariate t distribution vs. priors)
- Changes in the method used for numerical integration (SIR vs. MCMC)
- Changes in the methods used to weight the CPUE time series (various methods, but mostly equal weighting vs. inverse variance weighting)
- Changes in the models (surplus production, delay-difference, fully age-structured, "maximum likelihood")

2. METHODS AND MODELS

2.1. Catches and Catch Rates

Catch histories of the large coastal shark complex, sandbar, and blacktip shark for the various scenarios identified in NMFS (2002) are presented in **Tables 1-7**. **Tables 1-3** correspond to the ***updated scenario*** for the large coastal shark complex, sandbar, and blacktip shark, respectively, and consisted of updating the catches used in the 1998 SEW up to 1997, and adding catches for 1998-2001. **Tables 4-6** correspond to the ***baseline scenario*** for the large coastal shark complex, sandbar, and blacktip shark, respectively, and include discards from the menhaden fishery and Mexican catches, and extend bottom longline discards back to 1981 and also commercial landings and recreational catches back to 1981 (for sandbar and blacktip shark). The ***alternative catch scenario*** for the large coastal shark complex presented in **Table 7** was an attempt to reconstruct historical catches back in time (NMFS 2002). Details on the derivation of and rationale for these catch series can be found in NMFS (2002). The base document for catches is SB-02-15.

A trial was also conducted to assess the sensitivity of results for the alternative catch scenario to adjustments in the menhaden fishery discards series. In this scenario, the historical effort (starting in 1964) of the menhaden fleet in the Gulf of Mexico was used to develop an index to adjust the annual estimates of large coastal shark discards. This index was calculated by dividing the effort (given as total number of boats) in each year by the average effort for the years for which discard estimates were available (from de Silva et al.'s [2001] publication). Effort estimates were obtained from Vaughan et al. (2000) for 1964-1997 and from J. Smith (NMFS Beaufort Laboratory, pers. comm.) for 1998-2001. Effort in 1960-1963 was assumed to be as in 1964. The index for each year was then multiplied by the average discard estimate for 1994-1995 (25,100 fish) to obtain an annual estimate of discards. This modified alternative catch series is presented in **Table 8**.

The CPUE series used in the updated scenario were series previously used in the 1998 SEW, extended to include up to 2001 if available. For the large coastal shark complex, they included the Brannon (in numbers), Hudson, Crooke LL, Jax, NC#, Pt. Salerno, Tampa Bay, and Charterboat series exactly as used in the 1998 SEW, and the Shark Observer, SC LL (split into two series: recent and early),Virginia LL, LPS, pelagic logbook (PLL), recreational (split into two series: early and late; these series were referred to as MRFSS,HBOAT,TX1 and TX2 in the 1998 SEW), NMFS LL NE (split into two series: early and late), and NMFS LL SE series updated (and modified if subjected to a new analysis) up to 2001. A total of 19 series was thus used for the updated scenario of the large coastal shark complex.

For sandbar shark, the 10 series included in the updated scenario were all updated with respect to the values presented in the 1998 SEW. They were: Virginia LL, PLL, early and late Rec, early and late NMFS LL NE, NMFS LL SE, recent and early SC LL, and Bottom LL Logs ST (a similar series referred to as Gulf reef logs was used in the 1998 SEW). For blacktip shark, the 8 series included in the updated scenario were all updated with respect to the values presented in the 1998 SEW. They were: PLL, early and late Rec, Shark observer, early and late NMFS LL NE, NMFS LL SE, and BLL Logs ST.

The CPUE series used in the baseline scenario included those in the updated scenario and new series that became available since the 1998 SEW was conducted or that had not been used for that assessment, and were deemed appropriate for use in the baseline analyses. For the large coastal shark complex, the Driftnet observer series was added to the baseline scenario. A total of 20 series was thus used for the baseline scenario of the large coastal shark complex. For sandbar and blacktip shark, the baseline scenario included the same series as those used in the updated scenario. The same CPUE series used for the baseline scenario were used in the alternative catch scenario for the large coastal shark complex.

Sensitivity analyses of the effect of adding or removing certain time series to and from the baseline scenario were also carried out. They included considering only fishery-dependent or fishery-independent series, adding the BLL Logs ST series (large coastal shark complex), adding the LPS and/or Shark observer series (sandbar shark), and adding the Driftnet observer and/or the SC LL recent series (blacktip shark).

Age-specific CPUE series were added in the age-structured analyses for sandbar and blacktip sharks. A total of 15 CPUE series was used for sandbar shark. They included four Virginia LL series for ages 0-1, 2-7, 8-12, and 13-maximum age (and an additional biomass-based series for all ages), the PLL series for mature individuals (age 13-maximum), early and late recreational series for ages 2-7, Shark observer for all ages, early and late NMFS LL NE for all ages, NMFS LL SE for all ages, recent SC LL for immature individuals (ages 0-12), BLL Logs ST for all ages, and LPS for all ages. A total of 14 CPUE series was used for blacktip shark. They included the PLL series for mature individuals (age 6-max), early and late recreational for ages 0-3, Shark observer for all ages, early and late NMFS LL NE for all ages, NMFS LL SE for all ages, BLL Logs ST for all ages, Driftnet observer for all ages, recent SC LL for immature individuals (ages 0-5), PC LL for ages 0-5, two PC gillnet series for age-0 and ages 1-5, and the Mote gillnet series for age-0 individuals.

The CPUE series of the large coastal shark complex, sandbar, and blacktip shark used in the updated, baseline, alternative catch, and age-structured analyses are listed in **Appendix 1**. Details for these series can be found in Table 8 of the 2002 SEW Meeting Report (NMFS 2002) and in documents SB-02-6, 7, 8, 9, 12, 16, 21, 23, 28, 32, 33, 33r, and 34.

2.2. Stock Assessment Models

2.2.1. Bayesian Surplus Production Model using the SIR algorithm and several weighting schemes

The surplus production model applied in the 1998 SEW using Bayesian statistical techniques was a modified Schaefer model that had been previously used in the 1996 SEW (NMFS 1996). This version of the Schaefer model was proposed by Prager (1994) and includes fishing mortality (F) explicitly in the surplus production function, such that when population abundance is expressed in numbers, it becomes:

$$\frac{dN_t}{dt} = (r - F_t)N_t - \frac{r}{K}N_t^{\,2}$$

where N_t is stock abundance in year t, r is the intrinsic rate of increase from the logistic equation, K is carrying capacity, and F_t is the instantaneous fishing mortality rate in year t. After integration with respect to time and with $\alpha_t = r - F_t$ and $\beta = r/K$, the equation above can take two forms:

$$N_{t+1} = \frac{\alpha_t N_t e^{\alpha_t}}{\alpha_t + \beta N_t (e^{\alpha_t} - 1)}$$

when $\alpha_t \neq 0$, or

$$N_{t+1} = \frac{N_t}{1 + \beta N_t}$$

when $\alpha_t = 0$.

As detailed in Prager (1994) and McAllister et al. (2001), F_t must be solved iteratively from two different equations (when $\alpha_t \neq 0$ or when α_t=0) in which F_t occurs on both sides of the equation. The discrete version of the surplus production model without the Prager modification ($N_{t+1}=N_t+rN_t(1-(N_t/K))-C_t$; used by at least one of the two reviewers that attempted to duplicate results reported in the 1998 SEW report) was also used in the sensitivity analysis document (Cortes 2002a) and found to have little effect on results. Based on this, a specific sensitivity trial to determine the effect of using the continuous (Prager) vs. discrete form of the surplus production model was not attempted in the present assessment.

The expected catch rate (CPUE) for each of the available time series j in year t is given by:

$$\hat{I}_{j,t} = q_j N_t e^{\varepsilon}$$

where q_j is the catchability coefficient for CPUE series j, and e^{ε} is the residual error, which is assumed to be lognormally distributed. Coefficients of variation (CV) were available in some CPUE series ($CV_{j,t}$), and were used as weights for each series, such that:

$$\sigma_{j,t}^{\;2} = c_j CV_{j,t}^{\;2} \sigma_j^{\;2}$$

where c_j is a constant for series j that makes the weights sum to 1, and σ_j^2 is the arithmetic mean for the variance of CPUE series j.

The log likelihood function of the abundance indices is expressed as:

$$\ln L = -\sum_{j=1}^{j=s} \sum_{t=1}^{t=y} \left\{ \frac{0.5}{c_j CV_{j,t}^{\;2} \sigma_j^{\;2}} \left[\ln\left(\frac{I_{j,t}}{q_j N_t} \right) \right]^2 - 0.5 \ln(c_j CV_{j,t}^{\;2} \sigma_j^{\;2}) \right\}$$

where s is the number of CPUE series and y is the number of years in each CPUE series. This weighting scheme is an inverse variance method wherein annual observations are proportional to the annual CV^2 inputted and the average variance for each individual series is calculated as the MLE estimate (SB-02-26).

The average σ_j^2 and q_j for each CPUE series were assumed to follow a uniform distribution on a natural log scale, but were integrated from the joint posterior distribution using the method described by Walters and Ludwig (1994). In another form of the model, all CPUE data points from all series were assumed to have the same variance (σ^2=1), which is equivalent to having no weighting or having an equal weighting scenario. Additional weighting scenarios contained and described in detail in the BSP software (SB-02-26) were also used for one subset of runs to further assess the effect of weighting on results. These included 1) weighting by the MLE estimate of variance for each CPUE series; 2) treating the standard deviation for each series as a free parameter; 3) multiplying the inputted variances by a scale parameter; 4) inputting the variances for each series and adding a variance term that is an estimable parameter for each series; 5) inputting the variances for each data point and adding an estimated scale parameter; and 6) equal weighting wherein a single variance is estimated for all data points.

2.2.1.1. Prior probability distributions, alternative hypotheses, and performance indicators

Alternative hypotheses were generated by drawing alternative values from the parameters assigned priors (r, K, N_{1974}/K, and C_0). Performance indicators included the maximum sustainable yield (MSC=rK/4), the stock abundance in the last year of data (N_{2001}), the ratio of stock abundance in the last year of data to carrying capacity (N_{2001}/K), and the fishing mortality rate in the last year of data as a proportion of the fishing mortality rate at MSY (F_{2001}/F_{msy}).

The priors used were similar, but not identical, to those used in the 1998 assessment. The prior chosen for K was uninformative, as little is known about the carrying capacity of shark populations. The prior distribution for the large coastal shark complex, sandbar, and blacktip shark was uniform on the natural log of K over the range $1x10^6$ to $1x10^9$ individuals. This prior is proportional to the inverse of K and so assigns less credibility to higher values of K (McAllister and Kirkwood 1998).

The informative prior chosen for r was as in the 1998 assessment, and it was based on results from documents presented at the 1998 SEW (appendix 2 of the 1996 SEW [NMFS 1996]; SB-IV-10) and on some ad-hoc calculations undertaken during the 1998 Workshop. The upper bound, or absolute biological upper limit, of the intrinsic rate of increase assuming geometric growth was used in each case as the estimate of the mean. Note that the values used are higher than those used by McAllister et al. (2001). Thus, it must be noted that the values used in the 1998 SEW and herein are high from a biological perspective. Recent estimates of intrinsic rates of increase obtained using both density-independent (Cortés 2002c) and density-dependent (Smith et al. 1998) theory support considerably lower values of r for most species of sharks—including the sandbar and blacktip—in the large coastal complex (values of r for the most representative species all <0.07 for both density-independent and density-dependent estimates). While the surplus production model used assumes closed populations, it can be argued that the relatively high values of r used may be considered a proxy for net immigration into the stocks, thus alleviating to some extent the violation of a closed population assumption.

The priors for r were lognormal pdfs with mean=0.113, 0.117, and 0.136 for the large coastal complex, sandbar, and blacktip, respectively. The SD in the logarithm of r (σ_r) was set equal to 0.7 in all cases. It is calculated as (McAllister et al. 2001):

$$\sigma_r = \sqrt{\ln\left(1+\left(\frac{SD_r}{\overline{X}_r}\right)^2\right)}$$

This pdf makes values of r<0 impossible and concentrates most of the density towards the lower values of r. However, it also allows for high values of r that are unlikely for closed populations and even for open populations of sharks. Lower and upper bounds for these lognormal distributions were set at 0.001 and 2.0, respectively, in all cases.

Informative priors were also used to describe the ratio of the stock abundance in 1974 with respect to K (N_{1974}/K) and the average catch from 1974 to 1980 (C_0). For N_{1974}/K, the prior was lognormal with mean=1, SD in the logarithm of r of 0.20, and lower and upper bounds of 0.1 and 1.5, respectively, in all cases. This prior reduces the probability that N_{1974}/K will be much higher than K since most of the values will be closer to unity. The prior for C_0 was also lognormal with mean=487 300, 135 900, and 303 800 individuals (the mean of the observed catches during the period 1981-1997) for the large coastal complex, sandbar, and blacktip, respectively. The SD in the logarithm of C_0 was 0.51, 0.53, and 0.43, respectively. Lower and upper bounds were 10 000 and 5 000 000 individuals, respectively. **Table 9** summarizes all priors used in these analyses.

2.2.1.2. Methods of numerical integration

Numerical integration was carried out using the sampling/importance resampling (SIR) algorithm (Berger 1985, McAllister and Kirkwood 1998, McAllister et al. 2001) built in the BSP software. The marginal posterior distributions for each of the population parameters of interest were obtained by integrating the joint probability with respect to all the other parameters. Posterior CVs for each population parameter estimate were computed by dividing the posterior SD by the posterior expected value (mean) of the parameter of interest. Two importance functions were used in the SIR algorithm: the multivariate Student t distribution and the priors. For the multivariate Student t distribution, the mean is based on the posterior mode of θ (vector of parameter estimates K, r, N_{74}/K, and C_0), and the covariance of θ is based on the Hessian estimate of the covariance at the mode (see McAllister and Kirkwood [1998] and references therein for details). A variance expansion factor of 2 was generally used to make the importance function more diffuse (wider) and make sure that the variance of the parameters was not underestimated when using the multivariate Student t distribution (SB-02-25; SB-02-26).

2.2.1.3. Decision analysis

Posterior expected values for several indices of policy performance were calculated using the resampling portion of the SIR algorithm built in the BSP software, which involves randomly drawing 5,000 values of θ with replacement from the discrete approximation to the posterior distribution of θ, with the probability of drawing each value of θ being proportional to the posterior probability calculated during the importance sampling phase. Details of this procedure can be found in McAllister and Kirkwood (1998) and McAllister et al. (2001), and references therein. Once a value of θ was drawn, the model was projected from 1974 to 2001, and then forward, while applying one of the constant TAC (total allowable catch) policies (0%, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) from 2002 on. The projections included calculating the expected value of N_{fin}/K (with $_{fin}$=2011, 2021, and 2031), the expected value of the ratio of N_{fin} to the stock abundance that would result in MSY (N_{fin}/N_{MSY}), the probability that N_{fin} were $>N_{MSY}$, and the probability that N_{fin} were $>N_{2001}$.

2.2.1.4. Convergence diagnostics

To help ensure convergence of the results of the various stock assessment runs as well as an acceptable goodness of fit of the model to the data, the convergence diagnostic identified and described in document SB-02-25 was used. This diagnostic (which will be referred hereon as CV diagnostic) is the ratio of the CV of the weights to the product of the CV of the likelihood function and the prior distribution. Values <1 indicate convergence, whereas high values (>10) indicate likely failure of results to converge. In general, when the multivariate t distribution was used as an importance function, its variance was expanded as recommended in SB-02-25.

2.2.2. Bayesian Surplus Production Model using State-Space methodology and MCMC for numerical integration

A nonequilibrium Schaefer surplus production model was also used to describe the population dynamics of the large coastal shark complex, sandbar, and blacktip shark using state-space methodology and a Markov Chain Monte Carlo (MCMC) method for numerical integration as an alternative to the SPM described above (this was also done in Cortés 2000a,b). The model used was that described by Meyer and Millar (1999a), originally developed in BUGS, and recoded in WinBUGS (Spiegelhalter et al. 2000). In this approach, a state-space model accounts for both process error and observation error in a unified analytical framework that uses a MCMC method called Gibbs sampling (Gilks et al. 1996) to sample from the joint posterior distribution.

State-space models can be used to relate observed catch rates (I_t) to unobserved states (biomass, B_t) through a stochastic observation model for I_t given B_t. A description of state-space models can be found in Meyer and Millar (1999b) and Millar and Meyer (1999). Millar and Meyer (1999) implemented a nonlinear, nonnormal state-space model assuming lognormal error structures and a reparametrization by expressing the annual biomass as a proportion of carrying capacity ($P_t = B_t/K$). In the present implementation, this Bayesian model includes the joint prior distribution of all unobservable quantities, i.e., K, r, N_{1974}/K, $C_{0,}$ q, σ^2 (process error variance), and τ^2 (observation error variance) and the unknown states P_1,….,P_t, and the joint distribution of the observable quantities, i.e., the CPUE indices I_1,….,I_t. Bayesian inference then uses the posterior distribution of the unobserved quantities given the data (see Meyer and Millar 1999a for a full description of the model).

2.2.2.1. Prior probability distributions, alternative hypotheses, and performance indicators

Priors for r, K, N_{1974}/K, and C_0 were identical to those specified for the Bayesian SPM using the SIR algorithm. As in the original model developed by Millar and Meyer (1999), the present implementation used inverse gamma distributions as priors for σ^2 and τ^2, but the MLEs for q in each CPUE time series were used instead of one prior for q for each series. The geometric average of the time series of individual q estimates for each CPUE series was used as an analytic solution for the estimate of q that maximizes the likelihood function (Punt 1988; Hilborn and Mangel 1997):

$$\hat{q} = e^{\frac{1}{y}\sum_t \ln\left(\frac{I_t}{\hat{B}_t}\right)}$$

where y is the number of years in each CPUE series.

The prior for σ^2 was an inverse gamma distribution with the 10% and 90% quantiles set at 0.04 and 0.08, and the priors for τ^2 (one for each individual CPUE series) were also described by an inverse gamma distribution with the 10% and 90% quantiles set at 0.05 and 0.15. In an alternative scenario, one single value of τ^2 was used for all series and given an inverse gamma distribution. No CV^2 s were used in any of the scenarios run in WinBUGS. All runs were based on two chains of initial values (where the P_t values were set equal to 0.5 and 1.0, respectively) to account for over-dispersed initial values (Spiegelhalter et al. 2000), and included a 5,000 sample burn-in phase followed by a 50,000 iteration phase. **Table 9** summarizes all priors used in these analyses. Performance indicators included MSC, N_{2001}/K, the ratio of stock abundance in the current year to N_{MSY} (N_i/N_{MSY}), and the ratio of fishing mortality rate in the current year to F_{MSY} (F_i/F_{MSY}).

2.2.2.2. Convergence diagnostics

To test whether the MCMC algorithm had converged for the two chains used in the WinBUGS analyses, convergence diagnostics were implemented with BOA (Smith 2001). BOA, which is based on CODA (Best et al. 1995), is an S-Plus program that carries out convergence diagnostics of the output of WinBUGS and other Bayesian analysis software. The tests implemented included examining lags and autocorrelations of parameters, cross-correlations matrices, and the convergence diagnostics of Brooks, Gelman and Rubin (Gelman and Rubin 1992), Geweke (Geweke 1992), Heidelberger and Welch (Heidelberger and Welch 1983), and Raftery and Lewis (Raftery and Lewis 1992).

2.2.3. Bayesian LRSG Model using State-Space methodology and MCMC for numerical integration

A lagged recruitment, survival and growth (LRSG) model (Hillborn and Mangel 1997) was also used to model the dynamics of the large coastal shark complex, sandbar, and blacktip (this was attempted using data up to 1998 only in SB-02-11). This model is an approximation of the delay-difference model of Deriso (1980) and can be expressed in its discrete form as:

$$B_{t+1} = sB_t + R_t - C_t$$

where s is a compound parameter that describes how much the biomass changes from one year to the next as a result of survivorship resulting from natural mortality causes only, and growth in mass; R_t is recruitment to the population and is expressed as:

$$R_t = \frac{B_{t-L}}{a + bB_{t-L}}$$

where the term t-L indicates that recruitment in year t depends on the biomass L years before (Hilborn and Mangel 1997), and L refers to the time lag in years between reproduction and recruitment to the fishery. It is assumed that fish become vulnerable to the fishing gear and reach sexual maturity at the same age.

The parameters a and b are defined as:

$$a = \frac{B_0}{R_0}(1 - \frac{z - 0.2}{0.8z}),$$

$$b = \frac{z - 0.2}{0.8R_0}$$

where $R_0=B_0(1-s)$, and z is a parameter that represents the steepness of a Beverton-Holt stock recruitment curve, or the ratio between recruitment at $0.2B_0$ and R_0. A high value of z (=0.99) means that recruitment is almost constant and independent of spawning stock, whereas a low value of z (0.20) indicates that recruitment is proportional to spawning stock.

Performance indicators used included the biomass at MSY (B_{MSY}) and the maximum sustainable yield (MSY), which in this case are defined as:

$$B_{MSY} = \frac{1}{b}\sqrt{\frac{a}{1-s}} - a$$

and

$$MSY = B_{MSY}(s - 1 + \frac{1}{a + bB_{MSY}})$$

Other performance indicators included N_{2001}/K, N_i/N_{MSY}, the exploitation rate in the current year (exploitation rate=C_i/N_i), the harvest rate to produce MSY (H_{MSY}=MSY/ N_{MSY}), and the ratio of harvest rate in the current year to H_{MSY} (H ratio=exploitation rate/ H_{MSY}).

The model was also implemented in WinBUGS. As with the SPM, all runs were based on two chains of initial values (where the N_t values were set equal to low and high values, respectively) to account for over-dispersed initial values, and included a 5,000 sample burn-in phase followed by a 50,000 iteration phase. This implementation of the LRSG model was also a state-space model that accounted for both process and observation errors. As with the implementation to the surplus production model detailed above, observed catch rates (I_t) were related to unobserved states (abundance, N_t) through a stochastic observation model for I_t given Nt. The nonlinear, nonnormal state-space model also assumed lognormal error structures, but no reparametrization, i.e., the annual abundance (N_t) was used directly. The joint prior distribution of all unobservable quantities, i.e., N_0, z, s, q, σ^2 (process error variance), and τ^2 (observation error variance) and the unknown states $N_1,\ldots,N_N$, and the joint distribution of the observable quantities, i.e., the CPUE indices $I_1,\ldots,I_N$ were modeled.

2.2.3.1. Prior probability distributions, alternative hypotheses, and convergence diagnostics

Priors for all parameters were identical to those used in section 2.2 for the Bayesian state-space SPM. Additionally, an uninformative prior was chosen for the steepness parameter, z, i.e., a uniform distribution ranging from 0.2 (theoretical minimum) to 0.9. The prior chosen for s (the parameter combining survivorship and growth) was also uninformative. For the large coastal shark complex, a uniform distribution ranging from 0.60 to 0.95 was assumed for s, based on the rates of annual survivorship used to calculate intrinsic rates of increase in demographic analyses (SB-02-13) and on published growth information for large coastal sharks. The time lag between birth and recruitment to the fishery (L) was set at 10 years (it is recognized that this is a rough approximation) for the large coastal shark complex, based on the estimated ages at maturity for the individual species. For sandbar and blacktip sharks, z was also given a uniform prior ranging from 0.2 to 0.9, and s, a uniform prior ranging from 0.70-1.0 for sandbar shark and 0.75-1.0 for blacktip shark. **Table 9** summarizes all priors used in these analyses. Convergence diagnostics were as described in section 2.2.2.2.

2.2.4. Maximum Likelihood Estimation (MLE) Model

Parrack (1990) developed a model that produced maximum likelihood estimates of shark abundance. This model (described more fully in SB-02-04) had low demands for input—only a time series of effort and an annual estimate of catch (and its variance) or average individual weight (and its variance) and total annual yield. In proportion to the low input requirements, the output is quite simple: an estimate of the population trajectory for the time series of observations, an estimate of fishery-specific catchabilities, and a lumped parameter ("m") that represents the net annual change resulting from all inputs (reproduction, immigration) and outputs (natural mortality, emigration).

The model was derived by assuming a Poisson process for all natural changes in abundance. No stock-recruit function or carrying capacity of any sort is imposed on the population, and the model does not consider density-dependent changes in population dynamics. As a result, the population can only exhibit an increasing or decreasing trend (i.e., exponential increase or decay). The population will increase if $m>0$ and will decrease if $m<0$. For the models below, m was constrained to be greater than 0. If m were negative, this would imply a population that decreases annually even without fishing—such a population clearly cannot be fished sustainably. Fishing is modeled as a mid-year pulse. The model was implemented in AD Model Builder (Otter Research Ltd. 2000).

2.2.4.1. Model Input

Information existed to estimate fishery-specific parameters for the commercial fishery (using average individual shark weight and the variance associated with those weight estimates, and total landings) and the recreational fishery (using estimated total annual catch, and an estimate of the variance of annual catch). No estimates of average individual weight were available before 1994, so this was the first year that could be modeled. The last year of average weight estimates and variance estimates for annual catch was 2000. Thus, both updated and baseline models (see below) were constrained to the years 1994-2000. The only difference between the updated and baseline models was reflected in the total annual landings.

Effort was available in various measures for the commercial fishery: number of vessels, days away, number of trips, number of sets, total hooks, and hours fished. For all models, the number of sets was used as the commercial effort measure. For the recreational fishery, the only measure of effort was total angler trips. These are not target- specific trips. It was mentioned in SB-02-04 that a measure of effort that better represented trips targeting sharks might improve model performance. The same effort series were used for blacktip and sandbar shark.

The same estimates of average weight and variance of average weight were used for the commercial fishery for both updated and baseline models. The recreational fishery was modeled using total annual catch. While this changed between the updated and the baseline scenarios, the same estimate of catch variance was used.

SANDBAR SHARK

The **updated model** made use of the updated catch time series for the years 1994-2001. Thus, it was assumed that the MRFSS estimate of catch variance is representative of the true precision with which all catch (all recreational sectors and Mexican removals) is known. All model input is summarized in **Table 10**.

The **baseline model** made use of the same total landings for both commercial and recreational catch for the period 1994-2000. The difference between the two scenarios was the additional information regarding menhaden fishery bycatch and catch by Mexican fisheries in the baseline model. It was assumed that the Mexican fishery had similar selectivity and catchability to the recreational fishery, and Mexican catch was added to the recreational catch. Menhaden fishery bycatch was not included, as it was a very low number of removals, and it was not believed that this catch shared enough characteristics to be added directly to either commercial or recreational catch. All model input is summarized in **Table 11**.

BLACKTIP SHARK

The **updated model** made use of the updated catch time series for the years 1994-2001. Thus, it was assumed that the MRFSS estimate of catch variance is representative of the true precision with which all catch (all recreational sectors and Mexican removals) is known. All model input is summarized in **Table 12**.

The **baseline model** made use of the baseline catch time series for the years 1994-2001. The MRFSS estimate of variance for annual catch (derived for the catches in the updated model) was retained here. All baseline model input is summarized in **Table 13**. Only the estimate of recreational catch changed, reflecting different estimates for Mexican removals in 1994-2000.

2.2.5. Age-structured Surplus Production Model (ASPM)

Porch (2002a) developed a Bayesian, state-space implementation of an age-structured production model (SB-V-31). This model allows the user great flexibility in model structure and allows one to make use of existing information on demographic rates through Bayesian priors. The age-structured aspect of the model also permits incorporation of age-specific abundance indices.

All runs of this model used an equal weighting method in which all CPUE series and all points within each CPUE series were given equal weight. Compared to the model described in SB-V-31, the present version parameterized the recruitment function in terms of virgin recruitment (R_0) and survival of adults and pups. Previously, the recruitment function had been parameterized in terms of R_0 and the steepness of the stock-recruitment curve, but it was argued that little was known about steepness, whereas information existed for specifying priors of pup and adult survival (NMFS 2002).

2.2.5.1. Prior probability distributions and scenarios run

The following parameters were specified as Bayesian in the model: the historical rate of fishing (F_H), adult instantaneous natural mortality rate (M), virgin recruitment (R_0), pup survival, annual catchability constants, an effort constant per catch series, and annual deviations from each effort constant. For all sandbar shark models (updated and baseline scenarios), the following priors were used. F_H was specified as uniform over the range [0,2]. M was assumed to be constant for all ages after age 1, and was specified to be lognormal with mean 0.18 and CV=25%. Virgin recruitment was specified to be uniform on [10^4, 10^{11}]. Pup-survival was specified to be normal with mean 0.60 and CV=15%. Catchability parameters were specified as uniform on [10^{-14}, 1]. A constant effort parameter for each catch series was specified to be uniform on [10^{-1}, 10^7]. Random annual deviations for each effort constant were specified to be lognormal with mean 0, variance 1, and constrained to be in the interval [-5, 5]. There was no correlation assumed between these annual effort deviations.

For blacktip shark, F_H was specified as lognormal with mean 0.01 and a CV of 40%. M was assumed to be constant for all ages after age 1, and was specified to be lognormal with mean 0.22 and CV=35%. Virgin recruitment was specified to be uniform over the range [10^4, 10^{11}]. Pup-survival was specified to be normal with mean 0.52 and CV=35%. Catchability parameters were specified as uniform over the range [10^{-14}, 1]. A constant effort parameter for each catch series was specified to be uniform over the range [10^{-1}, 10^7]. Random annual deviations for each effort constant were specified to be lognormal with mean 0, variance 1, and constrained to be in the interval [-5, 5]. There was no correlation assumed between these annual effort deviations.

For both sandbar and blacktip shark, scenarios were run incorporating the updated catch and catch rates, and the baseline catch and catch rates. Within the updated and baseline scenarios, runs were done that incorporated only fishery-dependent or fishery-independent catch rates. Additionally, sensitivity trials were run to evaluate the effect that assumptions on fecundity can have on results.

SANDBAR SHARK

The **updated models** for sandbar shark made use of the updated catch (**Table 2**). The unreported catch was added to the commercial catch (the total remained the same) based on the assumption that it should have similar selectivity and catchability. A total of 15 CPUE indices were used (described in section 2.1 and listed in **Appendix 1**), starting in 1986. Based on these age-specific CPUE indices, six selectivity functions were used (**Table 14**).

Additionally, the commercial catch series was linked (i.e., assumed to have the same catchability) to the Shark observer CPUE series, the recreational catch series for 1986-1993 was linked to the early Rec CPUE series, and the recreational catch series for 1994-2000 was linked to the late Rec CPUE series. Separate catchability parameters were estimated for the remaining CPUE series. For the trial that used only fishery-dependent series, the same links between catches and catch rates were established. For the trial that used only fishery-independent series, no links between catches and catch rates were established: a separate catchability parameter was estimated for each catch series and each CPUE index.

The **baseline models** for sandbar shark made use of the baseline catch (**Table 5**). As with the updated models, the unreported catch was added to commercial catch. The same 15 CPUE indices were also used (extending back to 1981), and a 16th series (SC LL early, which consisted of two points only) was added. This series was not used in the updated models because it had only 1 observation in 1986-2001, but for the period 1981-2001 there were 2 observations. The same selectivity functions as in the updated models were used (**Table 14**). In addition, for the menhaden fishery bycatch, it was assumed that all ages were selected equally. The same assumptions on catchability as in the updated models applied to the baseline models and the corresponding trials with fishery-dependent and fishery-independent CPUE series only.

The **sensitivity runs for the fecundity assumption** involved testing the sensitivity of the model to the assumed level of pup production. The ASPM model of Porch (2002a) allows one to calculate the stock-recruit relationship based on weight (spawning stock biomass) or on actual fecundity values (in this case, age-specific number of pups per adult female). If one chooses to use weight, the implication is that fecundity increases with weight. In the case of sharks, this can certainly be true, but there is a physical limit to the number of pups that a female can carry. Sminkey and Musick (1996) estimated the mean litter size of sandbar sharks to be 8.4 pups with a standard deviation of 2.3 (and the range was expected to be 4-12 pups). Values from 8.5 – 40 were tested. A value of about 39 pups per female corresponds to using weight as the measure of fecundity. Realistic values of pup production did not seem to produce believable output (although this may have been related to the sensitivity of the model to historic fishing level). For all sandbar shark models run, a fixed value of 12 pups per mature female was used, as this was the biological upper limit. Since the stock-recruit relationship is calculated based on actual fecundities, rather than using weight, this means that SSB is calculated as [Number of females] X [proportion mature at age] X [number of pups produced at age]. Thus, in the output, spawning stock biomass does not have units of weight, as the other models do, rather the units are total pups born to all mature females.

BLACKTIP SHARK

The **updated models** for blacktip shark made use of the updated catch (**Table 3**). As for sandbar shark, the unreported catch was added to the commercial catch (the total remained the same) based on the assumption that it should have similar selectivity and catchability. Mexican catch was added to either the early (1986-1993) or the late (1994-2001) recreational catch, assuming it had similar selectivity and catchability. A total of 14 CPUE indices were used (described in section 2.1 and listed in **Appendix 1**), starting in 1986. Based on these age-specific CPUE indices, four selectivity functions were used (**Table 15**). Selectivity functions were derived following the recommendations in the Final Meeting Report of the 2002 SEW (NMFS 2002) using age-frequency distributions constructed from sampled catches in the commercial and recreational fisheries. The commercial (COMM) function was logistic (0.8825, 2.6276) and was applied to the PLL, Shark observer, NMFS LL NE early and late, NMFS LL SE, BLL Logs ST, and Driftnet observer series; the recreational (REC) function was a gamma distribution (1.699,0.472) and applied to the early and late Rec series; the "age-0" function was a gamma distribution (8.2,0.115) and applied to the PC gillnet and Mote gillnet series; and the "age 1-5" function was logistic (25,-4.65) and applied to the SC LL recent, PC LL, and PC gillnet series.

As for sandbar shark, the commercial catch series was linked (i.e., assumed to have the same catchability) to the Shark observer CPUE series, the recreational catch series for 1986-1993 was linked to the early Rec CPUE series, and the recreational catch series for 1994-2000 was linked to the late Rec CPUE series. Separate catchability parameters were estimated for the remaining CPUE series. For the trial that used only fishery-dependent series, the same links between catches and catch rates were established. For the trial that used only fishery-independent series, no links between catches and catch rates were established: a separate catchability parameter was estimated for each catch series and each CPUE index.

The **baseline models** for blacktip shark made use of the baseline catch (**Table 6**). As with the updated models, the unreported catch was added to commercial catch and Mexican catch was added to early/late recreational catch. The same 14 CPUE indices (extending back to 1981) and selectivity functions as in the updated models were used (**Table 15**). In addition, a fifth selectivity function was created for the menhaden fishery bycatch, with all ages assumed to be selected equally. The same assumptions on catchability as in the updated models applied to the baseline models and the corresponding trials with fishery-dependent and fishery-independent CPUE series only.

The **sensitivity runs for the fecundity assumption** involved testing the sensitivity of the model to the assumed level of pup production, as was done for sandbar shark. Castro (1996) estimated a mean litter size of 3.85 pups with a standard deviation of 1.20 pups, and a range of 2-6 young. One might therefore consider a realistic upper limit to be 5-6 pups. All sensitivity runs had the same model structure as the updated scenario. It appears that using weight for fecundity is approximately the same as fixing the number of pups per mature female at 35. Of the models explored, only those using 4 or 5 pups fall in the realm of demographic reality. Higher values for fecundity (10, 22, or 35, e.g.) could only be justified from the perspective that the "extra" pups are coming from adults outside of some smaller, locally observed population (i.e., an open population model).

Estimates from the model were quite sensitive to the assumed level of pup production. Steepness estimates ranged from 0.267 to 0.703, which corresponds to SPR levels of 0.829 and 0.329, respectively. The low steepness estimates, corresponding to 4 pups, indicate that the rate of fishing at MSY is 0.066, while the highest steepness indicates a much greater rate of fishing could be sustained (F_{msy} = 0.298). In the absence of evidence to support an open-population model (no detection of immigration of reproductive adults, e.g.), it was decided to use a biologically realistic value for pup production. Thus, for all **updated** and **baseline** models, fecundity was fixed at 5 pups per mature female.

2.2.5.2. Projections

As in the decision analysis with the Bayesian SPM using the SIR algorithm (section 2.2.1.3.), projections from the ASPM models were made by fixing all future removals at one of the six constant levels of the 2000 catch specified (0%, 50%, 80%, 100%, 120%, and 150%) until 2030. For each scenario considered, probabilities were calculated that related projected biomass in years 2010, 2020, and 2030 to three reference biomass levels. Specifically, we compared future Spawning Stock Biomass to the estimated spawning stock biomass in year 2000 (SSB_{2000}), the level of biomass at MSY (SSB_{MSY}), and to (1-M)*SSB_{MSY}, where M is the instantaneous rate of natural adult mortality estimated from the ASPM.

The projections are based on 500 bootstrap trials. Only variability in the stock-recruit function was incorporated into the bootstrap, with a standard error of recruitment deviations of 0.35 and an autocorrelation of 0.5. These bootstraps ignore the variability associated with all other model estimates (e.g., natural mortality, fishing mortality) and therefore should be viewed with caution. Probabilities were calculated as the number of bootstrap trials out of 500 that were greater than or equal to the SSB target. All projections were done with the PRO-2BOX software (Porch 2002b).

3. RESULTS

3.1. Catches and Catch Rates

The relative catch rates (divided by the mean) used in the various scenarios for the large coastal shark complex, sandbar, and blacktip shark are shown in **Figures 1-3.** Each figure shows three views of the catch rates: A) for the whole period (1974-2001), B) for the period after the 1993 FMP measures were implemented (1993-2001), and C) for the period elapsed since the 1998 assessment was conducted (1998-2001). For the large coastal shark complex, the earliest starting series (Virginia LL) shows a decreasing trend from 1974 to 1992, followed by an increasing trend from 1993 to 1998, after which (1999-2000) this series remains fairly flat. The Crooke LL series, which spans 1975-1989, shows a decline from 1978 to 1989, and the Port Salerno series also shows a generally declining trend from 1978 to 1990 (**Figure 1A**). Most of the series spanning 1993 onwards show generally increasing trends: in addition to the already mentioned Virginia LL, the Shark observer, LPS, and NMFS LL SE series also have increasing tendencies. The PLL series is fairly flat, and the late recreational and the recent SC LL series show very slightly increasing trends, whereas the Driftnet observer series shows a generally decreasing trend (**Figure 1B**). From 1998 to 2001, the series are all fairly flat, with the exception of the NMFS LL SE series, which increases markedly from 1999 to 2001, and the PLL and Driftnet observer series, which increase and decrease slightly, respectively (**Figure 1C**).

For sandbar shark, the earliest starting index is also the Virginia LL series, which, despite having some missing years, shows a generally decreasing trend from 1974 to 1992 (**Figure 2A**), followed by a generally increasing trend from 1993 to 2000 (**Figure 2B**). The early Rec series, which spans 1981-1992, also shows a declining trend, which is followed by an increasing trend in the late Rec series from 1993 to 1998 (**Figure 2B**). The LPS series also shows a generally declining trend from 1986 to 2000 (**Figure 2A**), although the trend is fairly flat from 1993 to 2000 (**Figure 2B**), peaking in 2001 (**Figure 2C**). Most of the series spanning 1993 onwards show generally increasing trends: the Virginia LL, SC LL recent, PLL, BLL Logs ST, Shark observer, and late Rec series all show increasing tendencies (**Figure 2B**). For recent years, the Virginia LL (1998-2000), BLL Logs ST (1998-2001), and SC LL recent series (1998-2001) show fairly flat trends, the PLL and Shark observer series (1998-2001) slightly increasing trends, whereas the late Rec series (1998-2000) shows a decline and the LPS series a peak in 2001 (**Figure 2C**).

For blacktip shark, the earliest starting index is the early Rec series, which spans 1981-1993, is highly fluctuating, and shows no clear trend (**Figure 3A**). For the period 1993-2001, only the Bottom LL Logs ST series shows an increasing trend from 1996-2001, with the late Rec, PLL, and Shark observer series not showing a clear trend (**Figure 3B**). For the period 1998-2001, the Shark observer and late Rec series show slightly decreasing trends with low points in 2001 and 1999, respectively, whereas the PLL, BLL Logs ST, and NMFS LL SE (only 2 points) show a slightly increasing trend (**Figure 3C**).

Figures 4-6 show fishery-dependent CPUE series only for the large coastal shark complex, sandbar and blacktip, and **Figures 7-9** show fishery-independent CPUE series only for the same three groupings. **Figures 10** and **11** show age-specific CPUE series for the sandbar and blacktip shark, respectively.

For sandbar shark, series available for juveniles (ages 0-12) included the Virginia LL, SC LL (early and recent) and Rec (early and late). The early Rec series for juveniles shows a decreasing trend from 1981 to 1993, followed by a slight overall increase in the late Rec from 1994 to 2000 (**Figure 10A**). The fragmented Virginia LL series for sandbar sharks ages 0 and 1 starts high in 1980-1981, continues at a much decreased level during 1990-1993, and increases during 1995-2000, but not to the level of the early years. Something similar occurs with the Virginia LL series for subadults (ages 8-12), which starts high in 1980-1981, decreases very markedly during 1990-1993, and tends to stabilize during 1995-2001 at a much lower level than in the early years. The Virginia LL series for adolescents (ages 2-7) again starts high in 1980-1981, has very low values during 1990-1992, and shows a generally increasing trend during 1995-2000, again at a lower level than in the early years. The SC LL recent series shows a slightly increasing trend from 1995 to 2001, with a peak in 1999 (**Figure 10A**). The two series available for adults only (ages 13+) show conflicting trends: the fragmented Virginia LL series generally decreases, whereas the PLL series increases from 1994 to 2001 (**Figure 10B**). Series that included all age groups (**Figure 10C**) showed conflicting trends: while the Virginia LL (biomass), LPS, NMFS LL NE early and late (each with 2 data points only), and NMFS LL SE showed generally decreasing trends, the Shark observer and BLL Logs ST series showed increasing trends.

For blacktip shark, there were two series available specifically for age-0 individuals: the PC gillnet series, which showed an increasing trend from 1996 to 2001, and the Mote gillnet series, which did not show a strong trend, despite a peak in 1996 (**Figure 11A**). With the exception of the PC LL and the SC LL recent series for juveniles (ages 0-5), which showed a generally decreasing trend, the other three series available for juveniles (early and late Rec, and PC gillnet showed no clear pattern (**Figure 11A**). The only series available for adult blacktip sharks only (ages 6+), the PLL series, shows a slightly decreasing trend from 1992 to 2001 (**Figure 11B**). Series that included all age groups (**Figure 11C**) showed conflicting trends: while the BLL Logs ST, NMFS LL SE (fragmented), and NMFS LL NE early and late (each with 2 data points only) showed generally increasing trends, the Shark observer and Driftnet observer (fragmented) series showed decreasing trends.

3.2. Stock Assessment

3.2.1. Bayesian SPM using the SIR algorithm

3.2.1.1. Updated analyses

LARGE COASTAL SHARK COMPLEX

Results of the updated analyses for the large coastal shark complex with equal weighting were almost identical regardless of the importance function used. Stock abundance in 2001 (N_{2001}) and N_{2001}/K are about 2.5 times higher than the corresponding values reported for 1998 (NMFS 1998; Cortes 2002a), but are still under the level required for MSY (or Maximum Sustainable Catch [MSC]; used interchangeably here). The current (for 2001) fishing mortality rate is also about 1.5 times higher than required for MSC (F_{cur}/F_{msy}=1.53; **Table 17**). **Figure 12** shows the predicted abundance under the equal weighting scenario in relation to the CPUE series (scaled by the inverse of the catchability coefficient for each series and the overall mean for all series) used in the fitting. Using the inverse variance weighting method resulted in a much higher expected value of r and low value of K, with N_{2001}/K being 0.59 when the priors were used as the importance function (the CV diagnostic was 2.25; **Table 16**). Inflating the variance term to 5 did not have any effect on results.

Several other weighting methods were also attempted as a test for this scenario only. Weighting by the MLE estimate of variance for each CPUE series (using the priors as the importance function) produced similar results to those obtained with the inverse variance weighting method (N_{2001}/K=0.56; CV diagnostic=0.74; **Table 16**). Treating the σ for each series as a free parameter or using equal weighting with a single σ estimated for all data points (using the priors as the importance function in both cases) yielded very similar results, with K being a little higher and r a little lower, than in the equal weighting scenario. In both cases N_{2001}/K was 0.45 and the CV diagnostic=0.80. Multiplying the inputted variances by a scale parameter or inputting the variances for each series and adding a variance term that is an estimable parameter for each series again produced fairly similar results with N_{2001}/K=0.46 and 0.48, and the CV diagnostic=1.0 and 0.68, respectively. Finally, inputting the variances for each data point and adding an estimated scale parameter produced much higher K, MSC, N_{2001}, and N_{2001}/K (0.69) estimates, with a CV diagnostic of 0.28.

Decision analysis of the consequences of alternative harvesting policies under the equal weighting scenario indicated that if the 2000 catch level were to be maintained, the large coastal shark complex would not be able to rebuild to MSC levels (e.g., there is a 67% probability that N_{2011} will be lower than N_{msy}; **Table 17**). However, a TAC of 80% of the 2000 catch would be close to achieving MSC in 10 years and a 50% TAC would reach and surpass MSC in 10 years. **Figure 13** shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for the large coastal shark complex. Predictions from the inverse variance weighting scenario were much more optimistic, indicating that even a TAC 1.5 times the 2000 catch would be sustainable.

SANDBAR SHARK

Results of the updated analyses for the sandbar shark with equal weighting and inverse variance weighting were very similar (**Table 18**) and suggest that the sandbar shark stock is at or slightly above MSY level (N_{2001}/K=0.50-0.52). The main difference with respect to the results of the 1998 assessment (NMFS 1998) and 2002 sensitivity analysis (Cortes 2002a) was that r values more than doubled, stock abundance in 2001 (N_{2001}) and MSC increased considerably, but K was only slightly lower than estimated in 1998. The CV diagnostics for both weighting schemes were 5.80 and 2.65, respectively (**Table 16**). **Figure 14** shows the predicted abundance under the equal weighting scenario in relation to the scaled CPUE series used in the fitting.

Decision analysis under the equal weighting scenario indicated that even the 1.5*C_{2000} TAC could allow MSY to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})$=67%, 73%, and 76%, respectively; **Table 18**). Predictions from the inverse variance weighting scenario were even slightly more optimistic. **Figure 15** shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for sandbar shark.

BLACKTIP SHARK

Results of the updated analyses for the blacktip shark with equal weighting and inverse variance weighting were also very similar (**Table 19**) suggesting that the blacktip shark stock is well above MSY level (N_{2001}/K=0.73-0.74). These results agree with those of the 2002 sensitivity analysis (Cortes 2002a) using equal weights. The CV diagnostics for both weighting schemes were 2.24 and 1.82, respectively (**Table 16**). **Figure 16** shows the predicted abundance under the equal weighting scenario in relation to the scaled CPUE series used in the fitting.

Decision analysis under the equal weighting scenario indicated that even the 1.5*C_{2000} TAC could allow MSY level to be reached after 10 20, or 30 years (($P(N_{fin}>N_{msy})$=80%, 74%, and 71%, respectively; **Table 19**). Predictions from the inverse variance weighting scenario were even slightly more optimistic. **Figure 17** shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for blacktip shark.

3.2.1.2. Baseline analyses

LARGE COASTAL SHARK COMPLEX

Results of the baseline analyses for the large coastal shark complex with equal weighting were similar to those of the updated scenario (**Table 20**). N_{2001} and MSC were higher, whereas N_{2001}/K was somewhat lower (0.35 vs. 0.39). Using the inverse variance weighting method with the priors as an importance function resulted in a very low expected value of r and a similar value of K, and accordingly N_{2001}/K was very low (0.14; **Table 20**). The CV diagnostics for both weighting schemes were 0.86 and 1.0, respectively (**Table 16**). **Figure 18** shows the predicted abundance under the equal weighting scenario in relation to the scaled CPUE series used in the fitting.

Decision analysis under the equal weighting scenario indicated that a TAC between 50% and 0% (no catch) of the 2000 catch level would likely be required for the large coastal shark complex to rebuild to MSY levels after 10 years, and that a 50% TAC would likely allow rebuilding after 20 years (($P(N_{2021}>N_{msy})$=58%; **Table 20**). Predictions from the inverse variance weighting scenario were much more pessimistic, indicating that even a no catch policy would be insufficient to permit rebuilding to MSY levels after 30 years. **Figure 19** shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for the large coastal shark complex.

SANDBAR SHARK

Results of the baseline analyses for the sandbar shark with equal weighting and inverse variance weighting using the priors as an importance function in both cases were not dissimilar (**Table 21**) and were similar to those of the updated scenario. The main conclusion that the stock is at or slightly above MSY level was maintained (N_{2001}/K=0.50-0.55) in these applications. The CV diagnostics for both weighting schemes were 2.05 and 3.12, respectively (**Table 16**). **Figure 20** shows the predicted abundance under the equal weighting scenario in relation to the scaled CPUE series used in the fitting.

As in the updated scenario, decision analysis under the equal weighting scenario indicated that even the 1.5*C_{2000} TAC could allow MSY level to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})$=64%, 68%, and 69%, respectively; **Table 21**). Predictions from the inverse variance weighting scenario were even slightly more optimistic. **Figure 21** shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for sandbar shark.

BLACKTIP SHARK

Results of the baseline analyses for the blacktip shark with equal weighting and inverse variance weighting using the priors as an importance function in both cases were close (**Table 22**) and somewhat more pessimistic than those of the updated scenario. The main conclusion that the stock is well above MSY level was maintained in these model applications (N_{2001}/K=0.68 in both cases). The CV diagnostics for both weighting schemes were 0.46 and 0.65, respectively (**Table 16**). **Figure 22** shows the predicted abundance under the equal weighting scenario in relation to the scaled CPUE series used in the fitting.

As in the updated scenario, decision analysis under the equal weighting scenario indicated that even the 1.5*C_{2000} TAC could allow MSY level to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})$=75%, 70%, and 67%, respectively; **Table 22**). Predictions from the inverse variance weighting scenario were even slightly more optimistic. **Figure**

23 shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for blacktip shark.

3.2.1.3. Alternative catch analyses

LARGE COASTAL SHARK COMPLEX

Results of the alternative catch scenario (which applied only to the large coastal shark complex) with equal weighting were similar to those of the updated scenario and hence slightly more optimistic than those of the baseline scenario (**Table 23**). K, N_{2001} and MSC were somewhat higher, r somewhat lower, but N_{2001}/K remained the same (0.39) as in the updated scenario. The CV diagnostic was 0.79 (**Table 16**). **Figure 24** shows the predicted abundance under the equal weighting scenario in relation to the scaled CPUE series used in the fitting.

Decision analysis under the equal weighting scenario indicated that a TAC of 50% of the 2000 catch could promote reaching and surpassing MSY level after 10 years (($P(N_{2011}>N_{msy})$=54%; **Table 23**). **Figure 25** shows the projections of N/N_{msy} and F/F_{msy} under alternative harvesting policies in the equal weighting scenario for the large coastal shark complex.

3.2.1.4. Sensitivity analyses

In addition to examining the sensitivity of results to changes in computational issues (the importance function used, the variance expansion factor applied to the importance function, the method used to weight the CPUE series, the algorithm for numerical integration, the type of population dynamics model applied) and the catch series considered, other sensitivity tests were performed, mainly dealing with the addition or deletion of specific sets of CPUE series. All sensitivity trials for the large coastal shark complex, sandbar, and blacktip shark incorporated changes to the baseline scenario.

3.2.1.4.1. Changes in the CPUE time series

3.2.1.4.1.1. Using fishery-dependent CPUE series only

LARGE COASTAL SHARK COMPLEX

This scenario made use of fishery-dependent CPUE series only. For the large coastal shark complex, this meant using 14 (7 commercial and 7 recreational) series: the Brannon, Hudson, Crook, Shark observer, Jax, NC#, Port Salerno, Tampa Bay, LPS, Charterboat, PLL, early Rec, late Rec, and Driftnet observer series. Results with equal weighting and inverse variance weighting became markedly more pessimistic than those of the baseline scenario (**Table 24**). K increased somewhat, but r, MSC, N_{2001}, and N_{2001}/K decreased significantly, especially when using inverse variance weighting (0.11).

The CV diagnostics were 0.91 for the equal weighting method (with the multivariate t as an importance function), and 0.88 for the inverse variance weighting method with the priors as the importance function (**Table 16**).

Decision analysis under the equal weighting scenario indicated that a no-catch policy would be required for the large coastal shark complex to rebuild to MSY levels only after 20 years (($P(N_{2021}>N_{msy})=56\%$; **Table 24**). Predictions from the inverse variance weighting scenario were considerably more pessimistic, indicating that even a no catch policy would be insufficient to rebuild to MSY levels after 30 years.

Adding the BLL Logs ST series to the 14 fishery-dependent CPUE series for the large coastal shark complex described above resulted in little change (**Table 25**). The CV diagnostic was 0.81 (equal weighting method with the priors as the importance function; **Table 16**). Decision analysis under the equal weighting scenario did not result in different conclusions from those found with the 14 fishery-independent CPUE series, indicating also that a no-catch policy would be required for the large coastal shark complex to rebuild to MSY levels only after 20 years (($P(N_{2021}>N_{msy})=61\%$; **Table 25**).

SANDBAR SHARK

For sandbar shark, considering only fishery-dependent series meant using 4 (2 commercial and 2 recreational) series only: the PLL, early Rec, late Rec, and BLL Logs ST series. Quantities estimated with equal weighting became somewhat higher, and those with inverse variance weighting, markedly higher than those of the baseline scenario (**Table 26**). K, MSC, N_{2001}, and N_{2001}/K increased, and r decreased (equal weighting) or increased (inverse variance weighting) by about 50%. In the equal weighting scenario, however, the current fishing mortality level was still 1.5 times above that required for MSY ($F_{2001}/F_{msy}=1.51$). In contrast, the inverse variance weighting scenario predicted that the current fishing mortality level was lower than F_{msy} ($F_{2001}/F_{msy}=0.61$). The CV diagnostics were 0.34 and 1.55 for the equal weighting method and the inverse variance weighting method (both with the multivariate t distribution as the importance function), respectively (**Table 16**). Decision analysis under the equal weighting scenario did not result in different conclusions from those found in the baseline analysis, indicating that even the $1.5*C_{2000}$ TAC option could allow MSY to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})=56\%$, 57%, and 58%, respectively; **Table 26**) under this model. Predictions from the inverse variance weighting scenario were considerably more optimistic.

Adding the Shark observer and LPS series to the 4 fishery-dependent CPUE series for sandbar shark described above resulted in markedly more pessimistic expected values, with N_{2001}/K decreasing from 0.52 to 0.32, and F_{2001}/F_{msy} increasing from 1.51 to 2.93 (**Table 27**). The CV diagnostic was 0.89 (equal weighting method with the multivariate t distribution as the importance function; **Table 16**). Consequently, the results of decision analysis under the equal weighting scenario also became more pessimistic, indicating that a no-take policy after 10 years or a 50% TAC after 20 years would be required for sandbar shark to rebuild to MSY levels (($P(N_{2011}>N_{msy})=51\%$ and ($P(N_{2021}>N_{msy})=57\%$, respectively; **Table 27**).

BLACKTIP SHARK

For blacktip shark, considering only fishery-dependent series meant using 5 (3 commercial and 2 recreational) series only: the PLL, early Rec, late Rec, Shark observer, and BLL Logs ST series. Results with equal weighting and inverse variance weighting became less optimistic than those of the baseline scenario (**Table 28**). N_{2001}/K and MSC decreased, and F_{2001}/F_{msy} increased, especially with the equal weighting scenario. The CV diagnostics were 0.38 and 23.35 for the equal weighting method and the inverse variance weighting method (with the priors and the multivariate t distribution as the importance function), respectively (**Table 16**). Decision analysis under the equal weighting scenario did not result in different conclusions from those found in the baseline analysis, indicating that even the 1.5^*C_{2000} TAC option could allow MSY level to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})=71\%$, 65%, and 61%, respectively; **Table 28**). Predictions from the inverse variance weighting scenario were considerably more pessimistic, but still indicated that a status-quo TAC (1^*C_{2000}) could still result in MSY level after 10 years (($P(N_{2011}>N_{msy})=54\%$; **Table 28**).

Adding the Driftnet observer series to the 3 fishery-dependent CPUE series for blacktip shark described above resulted in somewhat more pessimistic predictions when using equal weights (**Table 29**). The CV diagnostic was 0.32 (equal weighting method with the priors as the importance function; **Table 16**). Projections varied a little, indicating that the 1.5^*C_{2000} TAC option could allow MSY to be reached after 10 years, but only the 1.2^*C_{2000} TAC option could allow MSY to be reached after 20 or 30 years (**Table 29**).

3.2.1.4.1.2. Using fishery-independent CPUE series only

LARGE COASTAL SHARK COMPLEX

This scenario made use of fishery-independent CPUE series only. For the large coastal shark complex, this meant using 6 series: the SC LL early, SC LL recent, Virginia LL, NMFS LL NE early, NMFS LL NE late, and NMFS LL SE series. Results with equal weighting became markedly more optimistic than those of the baseline scenario (**Table 30**). K, r, MSC, and especially N_{2001} and N_{2001}/K, increased considerably, whereas F_{2001}/F_{msy} decreased considerably (from 2.04 to 0.89). For inverse variance weighting, while N_{2001}/K, MSC, and especially r (which tripled) increased, K and N_{2001} decreased, but F_{2001}/F_{msy} increased to a very high level (3.75). The CV diagnostics were 0.76 for the equal weighting method and 0.41 for the inverse variance weighting method with the multivariate t distribution and the priors as the importance function, respectively (**Table 16**).

Projections under the equal weighting or inverse variance weighting scenarios were both more optimistic than those of the baseline scenario. Under equal weighting, only the highest TAC option ($1.5*C_{2000}$) would not result in more than even odds of achieving MSY levels after 20 years ($P(N_{2021}<N_{msy})$=50%; **Table 20**). Under inverse variance weighting, only the $1.2*C_{2000}$ TAC or lower options would likely achieve the MSY goal after 10 years (($P(N_{2011}>N_{msy})$=69%).

SANDBAR SHARK

For sandbar shark, considering only fishery-independent series meant using 6 series: the Virginia LL, NMFS LL NE early, NMFS LL NE late, NMFS LL SE, SC LL early, and SC LL recent series. Results with equal weighting changed little with respect to those of the baseline scenario. Although N_{2001} and N_{2001}/K increased somewhat, MSC remained the same, and F_{2001}/F_{msy} increased a little (**Table 31**). Predictions from inverse variance weighting of indices became markedly more pessimistic, with MSC decreasing from 105 to 72 and N_{2001}/K from 0.50 to 0.39, and F_{2001}/F_{msy} climbing above 2. The CV diagnostics were 1.26 for the equal weighting method and 0.69 for the inverse variance weighting method with the priors as the importance function in both cases (**Table 16**).

Projections under the equal weighting scenario varied very little with respect to those of the baseline analysis and did not affect conclusions, whereas projections under the inverse variance weighting scenario became markedly more pessimistic, indicating that only a TAC option between no catch and 50% could result in MSY after 10 years ($P(N_{2011}>N_{msy})$=44-56%; **Table 31**).

BLACKTIP SHARK

For blacktip shark, considering only fishery-independent series meant using 3 series: the NMFS LL NE early, NMFS LL NE late, and NMFS LL SE series. Results with equal weighting and inverse variance weighting were similar to those of the baseline scenario and did not affect the prediction that the resource is well above MSY level (**Table 32**). The CV diagnostics were 1.70 for the equal weighting method and 1.29 for the inverse variance weighting method with the multivariate t distribution as the importance function in both cases (**Table 16**). Projections varied little with respect to those of the baseline analysis and conclusions were not affected.

Adding the SC LL recent series to the 3 fishery-independent CPUE series for blacktip shark described above resulted in very little change, with results being slightly less optimistic than those found with the 3 fishery-independent CPUE series only (**Table 33**). The CV diagnostic was 0.80 (equal weighting method with the multivariate t distribution as the importance function and a variance expansion factor of 2 instead of 1; **Table 16**). Projections varied little with respect to those obtained with the fishery-independent series only, and conclusions essentially remained unaltered.

3.2.1.4.1.3. Adding or removing specific CPUE series

LARGE COASTAL SHARK COMPLEX

Adding the BLL Logs ST series to the 20 CPUE series in the baseline scenario for the large coastal shark complex resulted in very little change when using equal weighting (**Table 34**), whereas the results became more optimistic with respect to the corresponding results in the baseline scenario when using inverse variance weighting and the priors as an importance function (most notably r increased from 0.04 to 0.27, MSC from 100 to 329, and N_{2001}/K from 0.14 to 0.37, and F_{2001}/F_{msy} decreased from 12.12 to 6.27; not shown). The CV diagnostics were 0.86 for the equal weighting method and 0.52 for the inverse variance weighting method with the multivariate t distribution and the priors as the importance function, respectively (**Table 16**).

Projections under the equal weighting scenario varied very little with respect to those from the baseline analysis, still indicating that a TAC between 50% and 0% (no catch) of the 2000 catch level would likely be required for the large coastal shark complex to rebuild to MSY levels after 10 years, and that a 50% TAC option could allow rebuilding after 20 years (($P(N_{2021}>N_{msy})$=61%; **Table 34**).

SANDBAR SHARK

Adding the Shark observer series to the 10 CPUE series in the baseline scenario for sandbar shark resulted in very similar predictions to those from the baseline scenario when using equal weighting (**Table 35**) and similar predictions when using inverse variance weighting. The CV diagnostics were 2.25 for the equal weighting method and 3.82 for the inverse variance weighting method with the priors as the importance function in both cases (**Table 16**). Projections under the equal weighting scenario varied little with respect to those from the baseline analysis, still indicating that even the $1.5*C_{2000}$ TAC option could allow MSY levels to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})$=68%, 72%, and 74%, respectively; **Table 35**).

Adding the LPS (recreational) series to the 10 CPUE series in the baseline scenario for sandbar shark resulted in more pessimistic predictions of stock status than in the baseline scenario, with N_{2001}/K=0.37 and 0.02 when using equal weighting (**Table 36**) or inverse variance weighting (not shown), respectively. In the latter case, the expected value of r was very low (0.04). The CV diagnostics were 1.50 for the equal weighting method and 1.11 for the inverse variance weighting method with the priors and the multivariate t distribution as the importance function, respectively (**Table 16**). Projections under the equal weighting scenario became markedly more pessimistic than those of the baseline analysis, indicating that a TAC option between 1 and $0.8*C_{2000}$ could be required to result in MSY after 10 years ($P(N_{2011}>N_{msy})$=48-55%; **Table 36**).

Adding both the Shark observer and the LPS series to the 10 CPUE series in the baseline scenario for sandbar shark showed that the LPS series had a much larger influence, resulting in predictions very close to those obtained when adding the LPS series only (**Table 37**). The CV diagnostics were 1.72 for the equal weighting method and 1.06 for the inverse variance weighting method with the priors and the multivariate t distribution as the importance function, respectively (**Table 16**). As when only the LPS series was added, projections under the equal weighting scenario became markedly more pessimistic than those of the baseline analysis, but still indicated that a TAC option between 1 and 1.2*C_{2000} could result in MSY levels after 10 years ($P(N_{2011}>N_{msy})$=47-54%; **Table 37**).

BLACKTIP SHARK

Adding the Driftnet observer series to the 8 CPUE series in the baseline scenario for blacktip shark resulted in similar predictions to those from the baseline scenario when using equal weighting (**Table 38**) or inverse variance weighting. The CV diagnostics were 0.36 for the equal weighting method and 56.22 for the inverse variance weighting method with the priors and the multivariate t distribution as the importance function, respectively (**Table 16**). Projections under the equal weighting scenario varied little with respect to those from the baseline analysis, still indicating that even the 1.5*C_{2000} TAC could allow MSY levels to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})$=67%, 62%, and 59%, respectively; **Table 38**).

Adding the SC LL series to the 8 CPUE series in the baseline scenario for blacktip shark resulted in very similar predictions to those obtained when adding the Driftnet observer series (above) when using equal weighting (**Table 39**) or inverse variance weighting. The CV diagnostics were 2.76 for the equal weighting method and 1.71 for the inverse variance weighting method with the multivariate t distribution as the importance function in both cases (**Table 16**). Projections under the equal weighting scenario thus varied little with respect to those from the baseline analysis and the scenario incorporating the Driftnet observer series, indicating that even the 1.5*C_{2000} TAC could allow MSY levels to be reached after 10, 20, or 30 years ($P(N_{fin}>N_{msy})$=70%, 66%, and 62%, respectively; **Table 39**).

Adding both the Driftnet observer and the SC LL series to the 8 CPUE series in the baseline scenario for blacktip shark resulted again in similar predictions to those obtained when adding either of these two series individually when using equal weighting (**Table 40**) or inverse variance weighting. The CV diagnostics were 0.34 for the equal weighting method and 0.29 for the inverse variance weighting method with the priors and the multivariate t distribution as the importance function, respectively (**Table 16**). Projections under the equal weighting scenario thus varied little with respect to those from the baseline analysis and the scenario incorporating the Driftnet observer series or the SC LL series, now indicating that the 1.5*C_{2000} TAC could allow MSY levels to be reached after 10 years ($P(N_{2011}>N_{msy})$=58%), and the 1.2*C_{2000} TAC option could allow

MSY levels to be reached even after 20 or 30 years ($P(N_{fin}>N_{msy})$=63% and 61%, respectively; **Table 40**).

3.2.1.4.2. Changes in the catch series

In this scenario the alternative catch history for the large coastal shark complex was adjusted to account for the level of effort in the menhaden fishery in the Gulf of Mexico. This change had an insignificant effect on results and projections (**Table 41**).

3.2.2. Bayesian State-Space SPM and LRSG models using MCMC

3.2.2.1. Updated analyses

LARGE COASTAL SHARK COMPLEX

Results of the updated analyses for the large coastal shark complex using the state-space SPM with the MLE of q for each series, 1 σ^2 (process error variance), and 1 τ^2 (observation error variance) for each series (form 1) were more optimistic than those obtained with the Bayesian SPM using the SIR algorithm and equal weights (**Table 42**). When using the MLE of q for each series, 1 σ^2, and 1 τ^2 for all series (form 2), results were a little less optimistic. The main difference of the WinBUGS SSSPM results with respect to those of the Bayesian SPM using the SIR algorithm was the higher expected value of r, which resulted in higher estimates of stock abundance in 2001 (N_{2001}), MSC, and N_{2001}/K. The posterior distributions of K, r, MSC and N_{2001} were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters.

Relative stock abundance (N/N_{MSY}) from 1974 to 1989 was estimated by the two forms of the model to be above 1, but was below 1 from 1990 on (**Figure 26A,C**). The relative fishing mortality (F/F_{MSY}) trajectories were below 1 from 1974 to1985, with the exception of 1983, and above 1 from 1986 to 2001, with the exception of 1999-2001 for form 1 of the model (**Figure 26B**) and 1999 for form 2 of the model (**Figure 26D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 27**. The fit to most series was good, except for that to the Port Salerno (recreational) CPUE series.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations for each chain usually started high but quickly decreased after a lag of 50 iterations only, suggesting that convergence to the posterior was not slow. Cross-correlation matrices showed that some parameters had fairly high correlations, as expected, but in general most correlations between parameters were fairly low, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic, which examines the two chains combined, had corrected scale reduction factors approximately equal to one, or the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution, which means that descriptive statistics could be calculated from the combined second half of the iterations from the two chains (Smith 2001). Most of the p values of the Z-score in the Geweke convergence diagnostic were <0.05 for chain 1, indicating that there was evidence against convergence. P values for chain 2 were much higher (>0.05), although some were still <0.05. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test. In contrast, the stationarity test indicated that K, r, C_0, and N_{2001} in chain 1 and N_{2001}/K in chain 2 failed this test, suggesting that the number of iterations for the MCMC sampler was not sufficient for convergence. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for most parameters was not sufficient. The burn-in period was sufficient for all parameters, but most of the dependence factors were >5, providing evidence against convergence, and consequently a higher thinning rate (the rate at which every ith iteration in each chain is selected to contribute to the statistics being calculated) was advised.

In limited testing, Cortés (2002b) found that increasing the thinning rate to 5 produced nearly identical results to those obtained with a thinning rate of 1, yet computing time increased considerably. Spiegelhalter et al. (2000) indicated that the main advantage of increasing the thinning rate is to reduce autocorrelations. Based on these considerations, while it is acknowledged that increasing the thinning rate could improve convergence, runs of 50,000 iterations with a thinning rate of 1 were maintained.

Results of the updated analyses for the large coastal shark complex using the state-space LRSG with form 1 of the model were less optimistic than those obtained with the state-space SPM and N_{2001} and N_{2001}/K closer to the findings from the SIR-based SPM (**Table 42**). When using form 2 of the model, results were even less optimistic. The posterior distributions of N_0, MSC, and N_{2001} were highly skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. The posterior for the parameter incorporating survival and growth, s, favored higher values, but was skewed to the left. The posterior for the steepness parameter, z, also tended to indicate that higher values were favored (the theoretical maximum is 1), ending abruptly on the imposed upper limit of 0.9.

Relative stock abundance (N/N_{MSY}) for the whole period (1974-2001) was estimated by the two forms of the model to be above 1, except for a dip below 1 from 1993 to 1996 for form 2 of the model (**Figure 28A,C**). Relative harvest rate (H/H_{MSY}) trajectories were below 1, except for 1983 and 1988-1998 for form 1 of the model, and 1983 and 1986-2001 for form 2 of the model (**Figure 28B,D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 29**. In this case the model did not have trouble with the fit to the Port Salerno series.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations for each chain usually started high but quickly decreased after a lag of 50 iterations; however, they remained high for some parameters (N_0 and N_{2001}) especially in chain 2. Cross-correlation matrices showed that some parameters had fairly high correlations, but in general most correlations between parameters were fairly low, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had corrected scale reduction factors approximately equal to one, or the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution. P values of the Z-score in the Geweke convergence diagnostic were all <0.05 in both chains, except for the p value of parameter z, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test. In contrast, the stationarity test indicated that N_0, N_{2001}, and s in chain 1 and N_0, N_{2001}, N_{2001}/K, and s in chain 2 failed this test, suggesting that the number of iterations for the MCMC sampler was not sufficient for convergence. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for N_0, N_{2001}, N_{2001}/K, and s in both chains. The burn-in period was sufficient for all parameters, but the dependence factors for N_0, N_{2001}, N_{2001}/K, and s in chain 1 and N_0, N_{2001}, and N_{2001}/K in chain 2 were >5, providing evidence against convergence, and consequently a higher thinning rate was advised.

SANDBAR SHARK

Results of the updated analyses for sandbar shark using the state-space SPM with form 1 of the model were much more optimistic than those obtained with the Bayesian SPM using the SIR algorithm and equal weights (**Table 43**). Using form 2 of the model resulted in somewhat less optimistic predictions. The main difference between the WinBUGS SPM results and those of the Bayesian SPM using the SIR algorithm was the much higher (7 times) expected value of K, which resulted in much higher estimates of stock abundance in 2001 (N_{2001}; by an order of magnitude), MSC, and N_{2001}/K. The posterior distributions of K, r, MSC and N_{2001} were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters.

Relative stock abundance (N/N_{MSY}) from 1974 to 1987 was estimated by the two forms of the model to be above 1, below 1 from 1988 to 1996, and above 1 again from 1997 on (**Figure 30A,C**). The relative fishing mortality (F/F_{MSY}) trajectories were below 1 from 1974 to1987, above 1 from 1988 to 1991 or 1992, and again below 1 from 1992 or 1993 on, with the exception of 1994 for both forms of the model (**Figure 30B,D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 31**.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations decreased after a lag of 50 iterations. Cross-correlation matrices showed that some parameters had fairly high correlations, but in general most correlations between parameters were fairly low. The Brooks, Gelman and Rubin diagnostic had the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution, Most of the p values of the Z-score in the Geweke convergence diagnostic were <0.05 for chain 1, indicating that there was evidence against convergence. P values for chain 2 were much higher (>0.05), with only N_{2001}/K and N_{1974}/K still being <0.05. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test. In contrast, the stationarity test indicated that all parameters except r had failed the test in chain 1, whereas all parameters passed the test in chain 2. Thus, the number of iterations for the MCMC sampler produced the desired accuracy of the estimated posterior means in all cases, was sufficient for convergence in chain 2, but was insufficient for convergence in most cases in chain 1. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for K, N_{2001}, and N_{2001}/K for chain 1, and for N_{2001} and N_{2001}/K for chain 2. The burn-in period was sufficient for all parameters, but the dependence factors for K, N_{2001}, N_{2001}/K, and N_{1974}/K were >5 for both chains, providing evidence against convergence, and advising the use of a higher thinning rate.

Results of the updated analyses for sandbar shark using the state-space LRSG with form 1 of the model were much closer to those obtained with the Bayesian SPM using the SIR algorithm and equal weights than those obtained with the state-space SPM model (**Table 43**). Using form 2 of the model resulted in less optimistic predictions. The posterior distributions of N_0, MSC, and N_{2001} were highly skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. The posterior for s favored lower values, but was skewed to the right. The posterior for z favored higher values, ending abruptly on the imposed upper limit of 0.9.

Relative stock abundance (N/N_{MSY}) from 1974 to 2001 was estimated by the two forms of the model to be above 1, except for 1991 and 1992 for form 1 and 1991 for form 2 (**Figure 32A,C**). The relative harvest rate (H/H_{MSY}) trajectory was slightly below 1 from 1974 to1976, but remained above 1 from 1977 to 2001, except for 2000 when it dipped below 1, for form 1 of the model (**Figure 32B**). For form 2 of the model, the H/H_{MSY} trajectory was below 1 until 1984, above 1 from 1985 to 1998, and below 1 again during 1999-2001 (**Figure 32D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 33**.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations for each chain decreased after a lag of 50 iterations, although there were still high values, suggesting that convergence to the posterior was slow. In contrast, cross-correlation matrices showed that most parameters had fairly low correlations, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution. Most of the p values of the Z-score in the Geweke convergence diagnostic were <0.05 for both chains, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test, except for N_{2001} in chain 1. In contrast, the stationarity test indicated that all parameters in chain 2 failed the test, whereas only about half of the parameters passed the test in chain 1. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for N_0, N_{2001}, and N_{2001}/K for chain 1, and for N_0 and N_{2001}/K for chain 2. The burn-in period was sufficient in all cases, but the dependence factors, especially for N_0, N_{2001}, and N_{2001}/K, were >5 for both chains (although the magnitude was lower for chain 2), providing evidence against convergence, and advising the use of a higher thinning rate.

BLACKTIP SHARK

Results of the updated analyses for blacktip shark using the state-space SPM with form 1 of the model yielded lower values of K and N_{2002}, a value of r twice as large, but values of MSC and N_{2001}/K but very similar to those obtained with the Bayesian SPM using the SIR algorithm and equal weights (**Table 44**). Using form 2 of the model resulted in very pessimistic predictions, with a very low estimate of K and a very high estimate of r. For form 1 of the model, the posterior distributions of K, r, and especially, MSC and N_{2002}, were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. For form 2 of the model, the posterior for MSC had both a long left and right tail, and the posterior for r was not informative, indicating that there was little information in the data about r in this scenario.

Relative stock abundance (N/N_{MSY}) for the whole period (1974-2001) was estimated by form 1 of the model to be above 1 (**Figure 34A**), whereas in form 2 of the model it started dipping below 1 in 1990 and continued to decrease until 2001 (**Figure 34C**). The relative fishing mortality (F/F_{MSY}) trajectory was below 1 for the whole period, except 1994 when it reached 1, in form 1 of the model (**Figure 34B**). For form 2, it stayed under 1 during 1974-1988, but remained above 1 from 1988 on (**Figure 34D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 35**. The model had problems with the fit to the Shark observer series.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations for each chain decreased after a lag of 50 iterations. Cross-correlation matrices showed that some parameters had high correlations, but in general most correlations between parameters were fairly low, especially for chain 2, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had corrected scale reduction factors approximately equal to one, or the 0.975 quantile <1.2, except for N_{2001}/K, indicating that the samples from most parameters arose from the stationary distribution. Most of the p values of the Z-score in the Geweke convergence diagnostic were <0.05 for both chains, especially chain 1, indicating that there was evidence against convergence. The

Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test, whereas the stationarity test indicated that all parameters except N_{2001}/K in chain 1, and MSC, r, and N_{2001}/K in chain 2, had failed the test. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for K, N_{2001}, and N_{2001}/K for both chains. The burn-in period was sufficient for all parameters in both chains, but the dependence factors for K, N_{2001}, and N_{2001}/K were especially high for both chains, providing evidence against convergence and advising the use of a higher thinning rate.

Results of the updated analyses for blacktip shark using the state-space LRSG with form 1 of the model yielded lower values of K, N_{2001}, MSC, and N_{2001}/K than those obtained with the state-space SPM and the Bayesian SPM using the SIR algorithm and equal weights (**Table 44**). Using form 2 of the model resulted in very pessimistic predictions as was the case for the corresponding state-space SPM model. For form 1 of the model, the posterior distributions of N_0, MSC, and N_{2001} were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. For form 2 of the model, the posteriors for s and z were not smooth. The posterior for z was skewed to the left and tended to indicate that higher values were favored.

The N/N_{MSY} trajectory for the whole period (1974-2001) was estimated by form 1 of the model to be above 1, whereas in form 2 of the model it started dipping below 1 in 1990 and continued to decrease to very low values until 2001 (**Figure 36A,C**). The F/F_{MSY} trajectory was below 1 from 1974 to1981, and above 1 from 1982 on, with occasional dips below 1 in 1986 and 2001, in form 1 of the model (**Figure 36B**). In form 2 of the model, it always stayed well above 1, with very high values (>10) from 1994 on (**Figure 36D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 37**. As with the corresponding form of the SSSPM model, this model had problems with the fit to the Shark observer series.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations for each chain decreased after a lag of 50 iterations. Autocorrelations remained high for N_0, N_{2001}, and N_{2001}/K, especially for chain 1, suggesting that convergence to the posterior was slow for these parameters. Cross-correlation matrices showed that some parameters had high correlations, but in general most correlations between parameters were fairly low, especially for chain 2, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had the 0.975 quantile <1.2, except for N_0 and $N_{2001,}$ indicating that the samples from most parameters arose from the stationary distribution. Most of the p values of the Z-score in the Geweke convergence diagnostic were <0.05 for chain 1, indicating that there was evidence against convergence. P values for chain 2 were much higher (>0.05), but the P values for N_0, N_{2001}, and z were still <0.05. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test. In contrast, the stationarity test indicated that all parameters except C_0 and N_{1974}/K had failed the test in both chains, indicating that the number of iterations for the MCMC sampler did not produce the desired accuracy of the estimated posterior means in those cases. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for N_0, N_{2001}, and N_{2001}/K for both chains. The burn-in period was sufficient for all parameters in both chains, but the dependence factors for N_0, N_{2001}, and N_{2001}/K were especially high for both chains, providing evidence against convergence and advising the use of a higher thinning rate.

3.2.2.2. Baseline analyses

LARGE COASTAL SHARK COMPLEX

Results of the baseline analyses for the large coastal shark complex using form 2 of the state-space SPM were a little more optimistic than those obtained with the Bayesian SPM using the SIR algorithm and equal weights (**Table 45**). Results with form 1 were even more optimistic. When using form 2, K, MSC, and N_{2001} were higher than the values obtained with the SIR-based SPM, but r and N_{2001}/K were close (0.14 vs. 0.13 and 0.37 vs. 0.35, respectively). The posterior distributions of K, r, MSC and N_{2001} for both forms of the model were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters.

Relative stock abundance (N/N_{MSY}) from 1974 to 1989 was estimated by the two forms of the model to be above 1, but was below 1 from 1990 on (**Figure 38A,C**). The relative fishing mortality (F/F_{MSY}) trajectories were below 1 from 1974 to 1985, with the exception of 1983, above 1 from 1986 to 1998, and below 1 again in 1999-2001 for form 1 of the model (**Figure 38C**), but not for form 2 (**Figure 38D**). The model fits to the individual CPUE series (expected vs. observed) for form 2 of the model are shown in **Figure 39**.

Convergence diagnostics for form 2 of the model showed that parameter autocorrelations for each chain quickly decreased to low values after a lag of 50 iterations only, suggesting that convergence to the posterior was not slow. Cross-correlation matrices showed that most parameters had low correlations, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution. All p values of the Z-score in the Geweke convergence diagnostic were <0.05 except for N_{2001}/K in chain 1 and N_{2001}/K, MSC, and N_{1974}/K in chain 2, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test. The stationarity test indicated that only N_{2001}/K in chain 1 failed this test, indicating that the number of iterations for the MCMC sampler was sufficient for convergence. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95

was sufficient. This diagnostic also indicated that the number of iterations needed for K and N_{2001}/K was not sufficient. The burn-in period was sufficient for all parameters, but the dependence factors for K, N_{2001}, N_{2001}/K, and N_{1974}/K were >5, providing evidence against convergence for these parameters, and consequently a higher thinning rate was advised.

Results of the baseline analyses for the large coastal shark complex using the state-space LRSG with form 1 of the model were less optimistic than those obtained with the state-space SPM and the SIR-based SPM (**Table 45**). When using form 2 of the model, results were more pessimistic. The posterior distributions of N_0, MSC, and N_{2001} were highly skewed to the right (not shown) for both forms of the model, indicating that there was still some density associated with high values of these parameters. The posterior for s favored higher values, but was skewed to the left, whereas the posterior for z favored lower values (especially for form 2 of the model) and its right tail ended abruptly towards the imposed upper limit of 0.9.

The N/N_{MSY} trajectory was estimated by form 1 of the model to be above 1 for the whole period (1974-2001), whereas for form 2 it decreased to below 1 starting in 1992 until 2001 (**Figure 40A,C**). The H/H_{MSY} trajectory was below 1 from 1974 to 1987, except for 1983, above 1 from 1988 to 1998, and below 1 during 1999-2001 for form 1 of the model (**Figure 40B**). For form 2, it was below 1 during 1974-1981, and above 1 during 1982-2001 (**Figure 40D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 41**.

Convergence diagnostics for form 1 of the model showed that parameter autocorrelations for each chain decreased after a lag of 50 iterations, although values for N_0 and N_{2001} remained very high, especially for chain 1. Cross-correlation matrices showed that some parameters had high correlations, as expected, but in general most correlations between parameters were fairly low, especially for chain 2, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had the 0.975 quantile <1.2, indicating that the samples from all parameters arose from the stationary distribution. Most of the p values of the Z-score in the Geweke convergence diagnostic were <0.05 for both chains, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test, whereas the stationarity test indicated that all parameters except N_0, N_{2001}, and s in chain 1, and additionally z and N_{1974}/K in chain 2, had passed the test. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for N_0, N_{2001}, and s for both chains. The burn-in period was sufficient for all parameters in both chains, but the dependence factors for N_0, N_{2001}, and s were especially high for both chains, providing evidence against convergence and advising the use of a higher thinning rate.

SANDBAR SHARK

Results of the baseline analyses for sandbar shark using the state-space SPM were much more optimistic than those obtained with the Bayesian SPM using the SIR algorithm and equal weights (**Table 46**). As in the updated case, the main difference between the WinBUGS SPM results and those from the Bayesian SPM using the SIR algorithm was the much higher (about 8 times) expected value of K, which resulted in much higher estimates of N_{2001} (by an order of magnitude), MSC, and N_{2001}/K. The posterior distributions of K, r, MSC and N_{2001} were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters.

As in the updated analyses, N/N_{MSY} from 1974 to 1987 was estimated by the two forms of the model to be above 1, below 1 from 1988 to 1996, and above 1 again from 1997 on (**Figure 42A,C**). F/F_{MSY} trajectories were below 1 from 1974 to1987, above 1 from 1988 to 1994 (with a dip below 1 in 1993), and again below 1 from 1995 on for both forms of the model (**Figure 42B,D**). The model fits to the individual CPUE series (expected vs. observed) for form 2 of the model are shown in **Figure 43**.

Convergence diagnostics for form 2 of the model showed that parameter autocorrelations for each chain were generally low after a lag of 50 iterations only, suggesting that convergence to the posterior was not slow. Cross-correlation matrices showed generally low correlations between parameters, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic had the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution. All p values of the Z-score in the Geweke convergence diagnostic were <0.05 except that for C_0 in chain 1 and those for C_0 and r in chain 2, indicating that there was little evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test. In contrast, the stationarity test for chain 1 indicated that all parameters except N_{1974}/K had failed the test in chain 1, whereas all parameters passed the test in chain 2. Thus, the number of iterations for the MCMC sampler produced the desired accuracy of the estimated posterior means in all cases, was sufficient for convergence in chain 2, but was insufficient for convergence in most cases in chain 1. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for K, N_{2001}, and N_{2001}/K for chains 1 and 2. The burn-in period was sufficient for all parameters, but the dependence factors for K, N_{2001}, N_{2001}/K, and N_{1974}/K were >5 for both chains, providing evidence against convergence, and advising the use of a higher thinning rate.

Results of the baseline analyses for sandbar shark using the state-space LRSG were much closer to those obtained with the Bayesian SPM using the SIR algorithm and equal weights than those obtained with the state-space SPM models (**Table 46**). The posterior distributions of N_0, MSC, N_{2001}, and N_{2001}/K were highly skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. The posterior for s favored lower values, but was skewed to the right. The posterior for z tended to indicate that higher values were favored, ending abruptly on the imposed upper limit of 0.9, and was skewed to the left.

The N/N_{MSY} trajectory during 1974-2001 was estimated by the two forms of the model to be above 1, except for a dip below 1 in 1991-1992 for form 1 and 1991 for form 2 (**Figure 44A,C**). The H/H_{MSY} trajectory was below 1 from 1974 to1983, but remained above 1 during 1984-2001 for form 1 of the model (**Figure 44B**), and was always above 1, except for a dip in 2000, for form 2 of the model (**Figure 44D**). The model fits to the individual CPUE series (expected vs. observed) for form 2 of the model are shown in **Figure 45**.

Convergence diagnostics for form 2 of the model showed that autocorrelations for some parameters (N_{2001}, N_0, and s) remained high after 50 iterations, suggesting that convergence to the posterior was slow for these parameters. Cross-correlation matrices showed that most parameters had fairly low correlations, thus not providing strong evidence for slow convergence to the posterior distribution. The 0.975 quantile in the Brooks, Gelman and Rubin diagnostic was >1.2 for several parameters (N_0, N_{2001}, N_{2001}/K, and s) indicating that the samples did not arise from the stationary distribution. Most of the p values of the Z-score in the Geweke convergence diagnostic were >0.05 for both chains, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test, but the stationarity test indicated that all parameters in chain 1 failed the test, whereas z and τ^2 were the only parameters to pass the test in chain 2. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was not sufficient for N_0, N_{2001}, and N_{2001}/K for both chains. The burn-in period was sufficient in all cases, but the dependence factors, especially for N_0, N_{2001}, and N_{2001}/K, were >5 for both chains, providing evidence against convergence, and advising the use of a higher thinning rate.

BLACKTIP SHARK

Results of the baseline analyses for blacktip shark using the state-space SPM with form 1 of the model yielded similar values of K, N_{2001}, and N_{2001}/K to, and higher values of MSC and r than, those obtained with the Bayesian SPM using the SIR algorithm and equal weights (**Table 47**). Form 2 of the model resulted in very pessimistic predictions, with a very low estimate of K and a very high estimate of r as in the updated analysis. For form 1 of the model, the posterior distributions of K, r, and especially, MSC and N_{2001}, were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. For form 2 of the model, the posterior for MSC had a long left tail, and the posterior for r was not informative, indicating that there was little information in the data about r in this scenario, as was the case for the updated analysis.

The N/N_{MSY} trajectory for the whole period (1974-2001) was estimated by form 1 of the model to be above 1, whereas in form 2 of the model it started dipping below 1 in 1990 and continued to decrease until 2001 (**Figure 46A,C**). The F/F_{MSY} trajectory was below 1 from 1974 to1987, and fluctuated above and below 1 from 1988 on in form 1 of the model (**Figure 46B**). In form 2 of the model, F/F_{MSY} was below 1 in 1974-1987 and remained above 1 in 1988-2001 (**Figure 46D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 47**. The model had problems with the fit to the Shark observer series as in the updated analysis.

Convergence diagnostics for form 1 of the model showed that autocorrelations for most parameters were low after 50 iterations. Cross-correlation matrices showed that some parameters had high correlations, as expected, but in general most correlations between parameters were fairly low, thus not providing strong evidence for slow convergence to the posterior distribution. The 0.975 quantile of the Brooks, Gelman and Rubin diagnostic was <1.2, except for $N_{2001}/K_{,}$ indicating that the samples from most parameters arose from the stationary distribution. The p values of the Z-score in the Geweke convergence diagnostic for C_0, N_{2001}/K, and r were <0.05 for chain 1 and most values were <0.05 for chain 2, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test, whereas the stationarity test indicated that K, MSC, N_{2001}, and N_{2001}/K in chain 1, and C_0, MSC, N_{2001}/K, r, and N_{1974}/K in chain 2, had failed the test. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was insufficient for K, N_{2001}, and N_{2001}/K for both chains. The burn-in period was sufficient for all parameters in both chains, but the dependence factors for K, N_{2001}, and N_{2001}/K were especially high for both chains, providing evidence against convergence and advising the use of a higher thinning rate.

Results of the baseline analyses for blacktip shark using the state-space LRSG with form 1 of the model yielded higher values of K, N_{2001}, and MSC, and a lower value of N_{2001}/K, than those obtained with the Bayesian SPM using the SIR algorithm and equal weights and with the state-space SPM (**Table 47**). As with the state-space SPM, form 2 of the model resulted in very pessimistic predictions, with very low estimates of K and especially N_{2001}/K. For form 1 of the model, the posterior distributions of N_0, N_{2001}, and MSC were skewed to the right (not shown), indicating that there was still some density associated with high values of these parameters. For form 2 of the model, the posteriors for the same parameters were even more highly skewed to the right, including that for N_{2001}/K.

The N/N_{MSY} trajectory for the whole period (1974-2001) was estimated by form 1 of the model to be above 1, whereas in form 2 of the model it started dipping below 1 in 1989 and continued to decrease until 2001 (**Figure 48A,C**). The H/H_{MSY} trajectory in form 1 of the model was below 1 from 1974 to1978, and above 1 in 1979-2000, dipping below 1 in 200l (**Figure 48B**). In form 2 of the model, H/H_{MSY} was below 1 only in 1974 and 1975, and progressively increased from 1976 on, reaching a maximum in 1995 (**Figure 48D**). The model fits to the individual CPUE series (expected vs. observed) for form 1 of the model are shown in **Figure 49**. The model had problems with the fit to the Shark observer series as in the updated analysis.

Convergence diagnostics for form 1 of the model showed that autocorrelations for several parameters were still high after 50 iterations. Cross-correlation matrices showed that some parameters had high correlations (especially some involving N_0), but in general most correlations between parameters were fairly low, thus not providing strong evidence for slow convergence to the posterior distribution. The 0.975 quantile of the Brooks, Gelman and Rubin diagnostic was <1.2, indicating that the samples from most parameters arose from the stationary distribution. The p values of the Z-score in the Geweke convergence diagnostic for most parameters were <0.05 for both chains, indicating that there was evidence against convergence. The Heidelberger and Welch halfwidth test indicated that all parameters in both chains had passed the test, whereas the stationarity test indicated that all parameters had failed the test, except for C_0, N_{1974}/K, and σ^2 in chain 1, and N_{1974}/K and σ^2 in chain 2. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was insufficient for N_0, N_{2001}, and N_{2001}/K for both chains. The burn-in period was sufficient for all parameters in both chains, but the dependence factors for N_0, N_{2001}, and N_{2001}/K were especially high for both chains, providing evidence against convergence and advising the use of a higher thinning rate.

3.2.3. MLE Model

3.2.3.1. Updated and baseline analyses

SANDBAR SHARK

The results of both updated and baseline models are presented in **Table 48**. Under both models, *m* was essentially zero. The estimates of total annual fishing mortality ranged from about 0.018 – 0.04 (**Table 49**). Since all F > *m*, the population declined steadily (**Table 49**). The estimate of population size in 2001 was very similar for the baseline and updated models.

Figure 50 shows the fit of predicted weight (or catch) to observed weight (or catch) for both updated and baseline models. The average weight of a commercially caught sandbar shark decreased through 1998, but has since increased. Recreational landings showed a parabolic trend with a peak in 1997. None of the fits were considered good.

In **Figure 51**, both updated and baseline models show the declining population trajectory (solid line). For both models, total fishing mortality was dominated by the commercial sector. Recreational fishing mortality was very low and fairly constant.

Comparing the effort time series (solid line) with the observed landings **in Figure 52**, it is easy to understand why the predicted landings fit so poorly. The commercial effort measure fluctuated almost every year, while the commercial landings declined sharply through 1997 and then increased slightly the last several years of data. The estimated commercial landings clearly reflect the "bumps" in the commercial effort measure, rather than the smooth trajectory of observed landings. The situation is even more accentuated for the recreational fishery—effort is fairly constant for most of the time series while catch follows a parabolic trajectory. It is not possible to scale the recreational effort to fit this sort of catch trend under the present model structure.

Because the model estimates a constant catchability per fishery and a constant m for the whole time series, the estimate of landings is a simple scaling of the overall observed effort. Because the population model is linear, the only possible equilibrium solution would be *m*=F. Since the models estimated a near-zero *m*, this would imply that the population cannot be harvested sustainably, except at very low levels. The Hessian matrix for the sandbar shark models was not positive-definite, implying that no standard deviations or correlations could be estimated.

Projections would be possible for this model, but the following assumptions would have to be made: effort remains constant at year 2000 levels, *m* remains at the estimated value, and the catchabilities do not change. However, as mentioned in the preceding paragraph, harvesting a population with the given *m* will only lead to further population decline unless Fs are at or below *m*.

BLACKTIP SHARK

The results of both updated and baseline models are presented in **Table 50**. A constant *m* was estimated for all years. Under both models, this value was near zero. A value of exactly zero would imply that the unfished population was stable, neither increasing nor decreasing. The estimated value implies a miniscule annual increase by a factor of e^m = 1.00000058 for the updated model and a factor of 1.00000034 for the baseline model. As these are very small values, any amount of fishing would be expected to cause the population to decrease. **Table 51** shows the annual estimates of fishery-specific instantaneous mortality. On average, the estimates for the baseline model were 4 times greater than for the updated model. In both cases, however, fishing mortality was much greater than *m*, and hence the population decreased in both cases. The final population size in 2001 was on the same order of magnitude (10^6), but was a little more than 4 times greater for the updated case (**Table 50**). Although the model converged, the Hessian matrix was not positive-definite, so no estimates of precision or correlation could be estimated.

Figure 53 shows the fit of predicted weight (or catch) to observed weight (or catch) for both updated and baseline models. The average weight of a blacktip shark caught by the commercial fishery increased throughout the time series. This trend was somewhat captured for the later years of the predicted weight series, but not very well.

Annual recreational catch fluctuated but without any overall trend for the updated model. The fit to catch was satisfactory in this case. In the baseline model, the estimated annual catch showed a somewhat decreasing trend overall, as a result of the Mexican catches (which declined for the baseline model but were fixed to be constant for the updated model).

In **Figure 54**, both the updated and baseline models show a declining population trajectory (solid line). Although the estimates of fishing mortality differ between the two scenarios, the ratio of commercial fishing to recreational fishing is very similar. With the exception of 1996 and 1998, the recreational fishing mortality was always greater than the commercial fishing mortality.

In **Figure 55**, effort (solid line) was superimposed on the fit to commercial and recreational landings. The same conclusion can be made for blacktip shark as for sandbar shark regarding sustainable harvest: with an *m* near zero, fishing at other than very low levels is not sustainable.

3.2.4. ASPM Model

3.2.4.1. Updated analyses

SANDBAR SHARK

For the model that utilized all 15 CPUE indices, a high level of F_H (0.0495) was estimated relative to $F_{current}$ (0.0002) and F_{MSY} (0.046) (**Table 52**). The influence of that parameter carried through the rest of the model parameter estimates: to compensate for historic overfishing ($F_H > F_{MSY}$) it estimated very large virgin stock values, and very low current fishing (**Table 52**). The result is also clear in **Figure 56**, where both B/B_{MSY} and F/F_{MSY} are near 0 (although B/B_{MSY} has "increased" from 1.6 E-4 in 1986 to 3.32 E-4 in 2001). The fit to catch was very good (**Figure 57**). The fit to the CPUE series was particularly poor for the Virginia LL age-specific indices, whereas the fit to the remaining indices was better in general terms (**Figure 58**).

When using only fishery-independent indices, the model tended towards a solution similar to that obtained when using all the indices, i.e., high historic F_H (0.0712) relative to $F_{current}$ (0.0000998) and F_{MSY} (0.064) (**Table 52**). Also, large virgin stock values and very low values for B/B_{MSY} and F/F_{MSY} were estimated.

In contrast to the previous results, the model using only fishery-dependent indices led to a very low estimate of F_H (2.04 E-8). Effectively, the model estimated no historic fishing and therefore the stock started at virgin conditions. This can be seen in the plot of B/B_{MSY}, where the value for 1986 is around 3 (approximately 3 x SSB_{MSY}/SSB_0). As would be expected, initiating fishing on a virgin stock, and at a value consistently above F_{MSY}, the annual estimate of B/B_{MSY} declined steadily and is currently estimated at 0.661 **(Figure 56**).

BLACKTIP SHARK

For the model that utilized all 14 CPUE series, the estimate of steepness was 0.330 (**Table 53**). The low reproductive potential implied by this steepness is reflected in the Spawning Potential Ratio at MSY (SPR_{MSY}) of 0.714. The current estimate of spawning stock biomass ($SSB_{current}$) is 91.4% of SSB_{MSY}. This proportion declined steadily from the start of the time series (1986) to the present, although the decline is less sharp in recent years (**Figure 59**). The decline is a result of the annual fishing rate being consistently above F_{MSY} = 0.116; the largest fishing rate occurred in 1992 (**Figure 59**).

The fit of predicted to observed catch was excellent (**Figure 60**). The fit to the CPUE series was moderately good, considering the spread of points for some indices and the small number of points for others (**Figure 61**). All predicted indices showed a declining trend (**Figure 61**), which is consistent with the trajectory of population abundance (**Figure 62**). It must be noted that, although this model converged, the Hessian matrix was not positive-definite. This prevented estimates of precision and also meant that it was not possible to perform a Markov Chain Monte Carlo routine to estimate the distribution of the posteriors.

When only fishery-dependent indices were used, the stock appeared to be slightly more productive: steepness was estimated to be 0.338 and SPR_{MSY} was 0.701. Because the stock was estimated to be more productive, estimates relating to population abundance were lower (R_0, SSB_0, $N_{current}$, and $B_{current}$) and the estimated rate of maximum sustainable fishing was greater (F_{MSY} = 0.122). The reference points F/F_{MSY} and SSB/SSB_{MSY} for the most recent year were less optimistic than those for the model using all indices (**Table 53** and **Figure 59**). The fit to catches was also excellent, and the fit to the CPUE series was similar to that for the model using all indices.

When only fishery-independent indices were used, the stock was estimated to be slightly less productive than for the previous two models: the estimate of steepness was 0.287 and SPR_{MSY} = 0.789. It follows logically that estimates relating to population abundance were greater (R_0, SSB_0, $N_{current}$, $SSB_{current}$) and the estimated rate of maximum sustainable fishing was lower (F_{MSY} = 0.082). The reference points F/F_{MSY} and SSB/SSB_{MSY} were the most optimistic of the three updated models: the current SSB is estimated to be 6.1% over the level producing MSY, and the current level of fishing is only 16% over F_{MSY} (**Table 53** and **Figure 59**).

3.2.4.2. Baseline analyses

SANDBAR SHARK

Both the model using all indices and the model using only fishery-independent indices gave results similar to those of the updated model that used fishery-*dependent* indices only: F_H was approximately 0, so SSB_{1981} was approximately equal to SSB_0 (**Table 52**). Unlike for the updated model with fishery-dependent indices only, however, F fluctuated around F_{MSY} through 1991 and then was consistently below (**Figure 56**). Consequently, although SSB/SSB_{MSY} decreased over the time series, it is still currently estimated to be greater than 1. The fit to catches was good, although the model had difficulty fitting the constant menhaden removal (**Figure 63**). The fit to the CPUE series was similar to the updated models, i.e., poor for the Virginia LL age-specific indices, and generally better for the remaining series (**Figure 64**). The model using only fishery-dependent indices did not converge, and there was insufficient time for finding the cause.

BLACKTIP SHARK

Compared to the models that used the updated catches, all baseline models showed an increasing population trend for the entire time series of data. In addition, comparing the estimated population size in 1986 (the first year common to both models), the estimate from the baseline model was 10 times larger (**Figure 62**). Numerous sensitivity runs were performed to try to determine which among several factors this difference could most likely be attributed to. One hypothesis is that the result was directly related to the fact that only one CPUE index had any observations for the period 1981-1985 (the early Rec series). The values for 1982-1985 were lower than the values for 1986-2001 **(Figure 11**), which caused that series to appear to have increased slightly. However, eliminating those points from the analysis did not cause much difference in the model estimates. In the end, it was not possible to determine what was the main factor responsible for the difference between the updated and baseline models.

For the model that used all 14 indices, the estimate of steepness (0.267) was lower than in the updated case, but so was the estimate of current fishing (0.00752; **Table 53**). In fact, the estimated trajectory of F/F_{MSY} was 4-10 times lower than in the updated case, and was always lower than 1, whereas the B/B_{MSY} trajectory was always greater than 1. This scenario thus indicated a population not depleted to below B_{MSY} and current fishing rate less than F_{MSY}. The fit to the catches was excellent (**Figure 65**), and the fit to the CPUE series shows a barely increasing line that bisects the cloud of observed points (**Figure 66**).

The models that used only fishery-dependent indices had great difficulty converging, as did the model that used only fishery-independent indices. Convergence was only attained when the model structure was altered (priors and/or bounds redefined or parameters fixed), which does not facilitate direct comparison with the other models for blacktip shark

3.2.4.3. Model projections from the updated and baseline analyses

SANDBAR SHARK

The updated ASPM models using all indices or only fishery-independent indices had estimated a historical fishing rate that was greater than F_{msy}, and hence the population was evaluated as being severely depleted (**Table 52**). This is evident in the projections of

SSB in **Figure 57a,c**, where the ratio of SSB to that of SSB at MSY is very low, but consistently increasing. The consistent increase is a result of $F_{current}$ being lower than F_{msy} (**Figure 58a,c**). The probability that the spawning stock biomass in 2010, 2020, and 2030 will be greater than the level in 2000 is 1 for these two scenarios (**Table 54)**. However, the probabilities associated with spawning stock biomass at MSY are all 0, indicating that even if no fishing took place through 2030, the stock would still not have recovered to MSY levels.

The remaining models that converged all estimated negligible historic catch, which meant that the stock started near virgin levels and thus the SSB trajectory started well above 1 **(Figure 57b,d,e**). Fishing rates that corresponded to the start of the time series were larger than F_{msy} (**Figure 58b,d,e**), which explains the downward trend in the SSB trajectory through the last year of observations (2001). For the updated model using only fishery-dependent indices, it appears that only a no-take policy or a 50% reduction of the 2000 catch are sustainable (**Figure 57b**), whereas for the baseline models using all indices or fishery-independent indices only, all of the catch scenarios are sustainable (**Figure 57d,e**; **Table 54**).

Sensitivity of the model outcomes to estimated historical F indicates that more informative priors for this parameter may be necessary to resolve the conflicting results.

BLACKTIP SHARK

The updated ASPM models estimated a historic catch rate that was about 10% of F_{msy} (**Table 53**), which meant that the level of spawning stock biomass at the start of the observations was above SSB_{msy} (**Figure 59a-c**). The estimate of current fishing rate is greater than that at MSY (**Table 53**; **Figure 60a-c**), which caused the consistent decline in the SSB trajectory through the last year of observations (**Figure 59a-c**). Among the updated models, only the catch scenario that reduces the 2000 catch by 50% consistently allows the level of spawning stock biomass to be above the target levels by the year 2030. For the updated model that used only fishery-independent indices (the most optimistic result), the scenario that reduces the 2000 catch by only 20% is also sustainable, and the scenario that held catches at year 2000 levels had probabilities of meeting the SSB targets in the range of 0.37-0.64 (**Table 55**; updated model with fishery-independent indices only). For none of the updated models did the increased catch scenarios meet SSB targets with an acceptable probability.

When the baseline catches were used, only the model using all indices converged properly. In this case, the rate of historic fishing was estimated to be about 20% of F_{msy} (**Table 53**). In addition, estimates of current fishing rate were lower than F_{msy} (**Table 53**; **Figure 60d**). As a result, SSB/SSB_{msy} was consistently greater than 1 for all projections (**Figure 59d**), and thus all catch scenarios were estimated to be sustainable (**Table 55**; baseline model with all indices).

Sensitivity of the model outcomes to estimated historical F indicates that more informative priors for this parameter may be necessary to resolve the conflicting results.

3.2.5. Summarized results

LARGE COASTAL SHARK COMPLEX

Figure 71 summarizes the predictions of current (for 2001) stock status of the large coastal shark complex obtained with the main scenarios from the Bayesian SPM models using the SIR algorithm and the WinBUGS SSSPM models. With the exception of the Bayesian SPM scenario that used only fishery-independent CPUE series, all the other scenarios depicted in the phase plot indicate that overfishing may be occurring and the resource may be overfished. If the level of catches in 2000 were maintained, there would be on average less than a 40% probability that the biomass in 2010, 2020, or 2030 would be above the present biomass (**Figure 72A**). If the level of catches in 2000 were reduced by 50%, there would be an average 50% probability that the biomass in 2010 would be above the biomass producing MSY, with that probability increasing the longer the time horizon considered (**Figure 72B**). If the 2000 catch were reduced by only 20%, the probability of reaching MSY even after 30 years would be less than 50% under that harvest policy (**Figure 72B**). These results could be considered contradictory with some of the species-specific results, since blacktip and sandbar sharks represent the bulk of the harvest from the large coastal shark complex. However, the catch and catch rate series used in the large coastal complex analyses represent a broad range of species, some of which are in apparent decline while others show signs of either increase or relative stability.

SANDBAR SHARK

Figure 73 summarizes the predictions of current stock status of sandbar shark obtained with the main scenarios from the Bayesian SPM models using the SIR algorithm, the WinBUGS SSLRSG models, and the ASPM models. The two baseline ASPM scenarios that converged (using all indices and only fishery-independent indices) predicted a healthy resource status, whereas the ASPM updated scenario that used only fishery-dependent indices and the Bayesian SPM that used all indices indicated that overfishing is occurring and resource abundance is below the MSY level. The ASPM scenarios, updated and updated with only fishery-independent indices, predicted that the resource was severely overfished (very low biomass), whereas the rest of scenarios indicated overfishing of the resource is occurring ($F>F_{MSY}$), but current abundance is above that producing MSY. This situation is reflected in the biomass projections shown in **Figure 74B**, where it can be seen that even an increase of 1.5 times the 2000 catch could result in approximately a 50% probability on average that the biomass in 2010, 2020, or 2030 would be above the biomass at MSY. **Figure 75** shows surface plots of the probability that the biomass in each individual model considered be greater than the biomass in 2000 (A) or the biomass at MSY (B) under each of the six harvesting policies for three time horizons (10, 20, and 30 years). The three-dimensional aspect of this figure allows one to simultaneously assess the sensitivity of the result to model structure and catch/cpue series considered ("Probability" versus "Model") as well as the sensitivity of the result to TAC policy ("Probability" versus "Multiple"). The deep folds in the left-most part of the surface are the result of the ASPM model runs, which converged on widely divergent solutions, depending on the indices included and the catch scenario considered (see **Table 52**). Thus, the ASPM models were very sensitive to the catch/cpue series included in the model, while they were not very sensitive to the TAC policy. In contrast, the production models were slightly more sensitive to the TAC policy than they were to the catch/cpue series.

BLACKTIP SHARK

Figure 76 summarizes the predictions of current stock status of blacktip shark obtained with the main scenarios from the Bayesian SPM model using the SIR algorithm, the WinBUGS SSSPM models, and the ASPM models. The majority of scenarios indicated that resource status is at or above B_{msy}, with only the three ASPM updated scenarios indicating that overfishing is occurring, and only two of those same models indicating that the biomass level is less than B_{MSY}. **Figure 77B** shows that when considering all the main models, even an increase of 1.5 times the 2000 catch could result in approximately a 50% probability on average of the biomass in 2010, 2020, or 2030 being above the biomass at MSY. **Figure 78** shows surface plots of the probability that the biomass in each individual model considered be greater than the biomass in 2000 (A) or the biomass at MSY (B) under each of the six harvesting policies for three time horizons (10, 20, and 30 years). In contrast to Figure 75 for sandbar shark, the ASPM models for blacktip shark were not nearly as sensitive to the catch/cpue series considered (although the model using baseline catches, BT_B, stands out from the cases using updated catch). All models were sensitive to the TAC policy considered. In particular, the surplus production models were more sensitive to TAC policy with respect to the probability that the projected biomass was greater than the level of biomass estimated in year 2000 (**Figure 78A**) than to the level of biomass at MSY (**Figure 78B**). The ASPM models were equally sensitive to TAC policy with respect to the probability that projected biomass was greater than the level of biomass estimated in year 2000 and the level of biomass at MSY (although model BT_B stands out as fairly insensitive).

4. DISCUSSION AND CONCLUSIONS

LARGE COASTAL SHARK COMPLEX

Results for the large coastal shark complex were sensitive to the weighting scheme used, with several methods indicating that some reduction in the fishing level is still necessary, and other methods indicating that the present fishing level (for 2001) is sustainable. The form of the model (state space vs. non-state-space), the population dynamics model (surplus production vs. simplified delay-difference model), and the method of numerical integration (SIR vs. MCMC) also affected results, but tended to support the conclusion that some level of reduction in fishing could be needed to recover the complex to levels that could sustain MSY. The catch series considered (updated, baseline, alternative) had a small effect on results when using the equal weighting method, but changed the sign of the predictions when using the inverse variance weighting method (e.g., N_{2001}/K was 0.59 for the updated scenario vs. 0.14 for the baseline scenario). Not surprisingly, the sets of CPUE series considered had a profound effect on results. Using only fishery-dependent series in the surplus production model fitting predicted a high level of depletion and the lowest odds of achieving MSY levels within the forecast, whereas considering fishery-independent series only, predicted that the present level of removals or even a 20% increase in catches could still result in abundance being above the MSY level in 10 years. These results are directly related to the trend seen in the two sets of CPUE series for the large coastal shark complex, which shows a general increase from the mid-1990's in the fishery-independent indices (**Figure 7B**).

In terms of the reliability of results, all results obtained with the Bayesian SPM using the SIR algorithm appeared to have converged according to the CV diagnostic used, with only the inverse variance method in the updated scenario having a higher value (2.25; **Table 16**). Convergence diagnostics for the Bayesian SSSPM and SSLRSG models using WinBUGS generally yielded mixed results, with some diagnostics failing to support lack of convergence and others supporting convergence failure. In general, the predictions of resource status from the WinBUGS SSLRSG models tended to approximate more those from the Bayesian SPM model, and were lower than those from the corresponding WinBUGS SSSPM models. The model fits to the CPUE series were good, with the exception of the fit to the Port Salerno series in one of the scenarios considered.

In all, results for the large coastal shark complex show that the status of the resource has improved since 1998. However, summarized results indicated that for the large coastal complex, overfishing may still be occurring and the resource complex may be overfished. A reduction in catch of 50% the 2000 catch level for the complex could be required for the biomass to reach MSY in 10 years. Given the results for sandbar and blacktip sharks (see below), reductions—if applied—to catch levels of other species in the complex would appear to be the most appropriate.

SANDBAR SHARK

Results for sandbar shark were rather insensitive to the catch series and weighting method used, and indicated that abundance levels are right at MSY or slightly above, although the equal weighting scenarios indicated that the current fishing level (for 2001) is still slightly above that which would produce MSY (**Tables 18** and **21**). As with the large coastal shark complex, the closest agreement between models was with the SPM/SIR model and the WinBUGS simplified delay-difference (SSLRSG) models, whereas the WinBUGS surplus production (SSSPM) models yielded very high estimates (**Tables 43** and **46**). Results from the WinBUGS models supported the findings from the SPM/SIR model that the resource is close to MSY levels.

The addition of the LPS fishery-dependent CPUE series changed the sign of the predictions. When this series was added to either the baseline series or the fishery-dependent CPUE series, current resource abundance was estimated to be below that producing MSY and current fishing mortality above that producing MSY (**Tables 27, 36,** and **37**). These results are directly related to the decreasing trend of the LPS series from 1986 to 2000 (**Figure 2A**). Not considering this series among the fishery-dependent indices resulted in more optimistic predictions than in the baseline scenario (**Table 26**) and adding the Shark observer series to the series in the baseline scenario resulted in little change (**Table 35**). Considering fishery-independent series only had little effect on results when using equal weighting, but resulted in more pessimistic predictions when using inverse variance weighting (**Table 31**).

The CV diagnostic values for the results obtained with the Bayesian SPM using the SIR algorithm for sandbar shark were generally higher than those found for the large coastal shark complex, with no clear trend between results obtained with equal weighting and inverse variance weighting. The majority of the CV diagnostic values, however, were above 1 (**Table 16**). As for the large coastal shark complex, convergence diagnostics for the WinBUGS models generated mixed results, with some diagnostics failing to support lack of convergence and others supporting convergence failure. In general, the predictions of resource status from the WinBUGS SSLRSG models tended to be closer to those from the Bayesian SPM model, and were lower than those from the corresponding WinBUGS SSSPM models. The model fits to the CPUE series were good.

For the MLE model, the fact that the model's behavior is limited to either exponential increase or exponential decline is unsatisfactory. In theory, one could solve for a sustainable level of harvest where $F_{Total} = m$. However, for the present models, all estimates of *m* were approximately zero, which implied that neither population (sandbar or blacktip shark) could be harvested.

In comparing **Figures 52** and **55** for the MLE model, the problem of using the same effort series to fit catch histories for two different species is highlighted. The greatest improvement for future runs of this model would be to obtain a more appropriate measure of effort that reflects targeted shark trips. Although the blacktip shark model fits looked fairly good, it cannot be determined whether this is a credible solution or a spurious one. In all, the main conclusion from the MLE model was that with a value of *m* near zero, fishing is not sustainable for either the sandbar or blacktip shark, except at very low levels.

Results from the updated and baseline age-structured production models (ASPM) were very different. The main difference in the data used for these two models was the catch series, which extended further back (1981 vs. 1986) in the baseline model, and the addition of a CPUE series for juveniles consisting of two points only in the baseline model. When considering the updated models, using all indices and only fishery-independent indices resulted in a relatively high estimate of historic fishing mortality (F_H, with $F_H > F_{MSY}$ and $F_H >> F_{current}$) and very large estimates of virgin conditions. In contrast, using only fishery-dependent indices led to an estimate of historic fishing that was effectively zero, with estimates of virgin conditions that were $10^5 – 10^6$ times lower than for the other two models. These results are at opposite ends of the spectrum. Some of the fishery-dependent results appear to be more likely; however, it is known that historic catch was taken so F_H cannot be zero. Better knowledge about the level of historic catch in relation to current catch ($F_H/F_{current}$) may make it possible to set a more informative prior for F_H.

Results from the baseline models using all indices and fishery-independent indices only were closer to the results from the updated model using fishery-dependent indices only. These baseline results, however, are still considerably more optimistic and indicate that current resource biomass is well above that producing MSY and fishing mortality below that producing MSY. These results, although not directly comparable to those of the surplus production models (the ASPM performance indicator for biomass refers to the Spawning Stock Biomass vs. the total stock biomass in the surplus production models; but both models use F/F_{MSY}), are in conflict with those from the surplus production model that included the LPS series. Again, it must be remembered that the baseline ASPM models estimated an extremely low value of historic catch, which is not very realistic, and therefore these results must be considered cautiously.

The range of results for sandbar shark thus includes conflicting predictions: 1) that no reduction in fishing mortality appears necessary to promote achieving B_{MSY}, as supported by the surplus production and simplified delay-difference models; 2) that fishing is not sustainable, as predicted by the MLE model; and 3) that the resource is either severely depleted, or alternatively, only lightly affected by fishing, as predicted by the updated and baseline ASPM models, respectively. Results from the MLE model seem unreasonable. Results from the ASPM model that predicted either extremely low values of historic fishing (and the most optimistic outcome) or very low values of current fishing (and the most pessimistic outcome), which essentially includes all results from the ASPM model, largely depend on estimated historic F, a parameter for which little information is available in the catch-effort time series.

In all, results for sandbar shark show that the status of the resource has improved since 1998. Summarized results indicated that overfishing of the resource may be occurring, but that current biomass appears to be at or above that producing MSY (**Figure 73**).

BLACKTIP SHARK

Results for blacktip shark were also rather insensitive to the catch series and weighting method used, and indicated that abundance levels are well above MSY and the current fishing level well below that which would produce MSY (**Tables 19** and **22**). Unlike with the other two groupings, the closest agreement between models was with the SPM/SIR model and the WinBUGS surplus production (SSSPM) form 1 (1 τ^2 for each series) of the model, with form 1 of the simplified delay-difference (SSLRSG) model being less close. Form 2 (1 τ^2 for all series) for both the SSSPM and SSLRSG models was very different, yielding very low estimates (**Tables 44** and **47**).

Considering only fishery-dependent series in the surplus production model fitting affected results very little when using equal weighting, but resulted in a more pessimistic outlook when using inverse variance weighting, indicating that current resource abundance would be just slightly below MSY yet current fishing level just slightly below MSY as well. However, there may have been convergence failure in the latter case (see below). Considering fishery-independent series only had little effect on results (**Table 32**), as did adding individual series to the fishery-dependent, fishery-independent, or baseline scenarios (**Tables 29**, **33**, **38**, **39,** and **40**).

The CV diagnostic values for the results obtained with the Bayesian SPM using the SIR algorithm for blacktip shark were generally higher than those found for the large coastal shark complex and lower than those for the sandbar shark. The majority of the CV diagnostic values were below 2, with two notable exceptions: the inverse variance weighting scenario when considering fishery-dependent CPUE series only (23.35) and when adding the Driftnet observer series to the baseline indices (56.22; **Table 16**). As was the case for the two other groupings, convergence diagnostics for the WinBUGS models generated mixed results, with some diagnostics failing to support lack of convergence and others supporting convergence failure. In general, the predictions of resource status from the WinBUGS SSSPM form 1 of the model tended to be closer to those from the Bayesian SPM model, and were higher than those from form 2 of the model or from the corresponding WinBUGS SSLRSG models. Some of the posteriors for form 2 of the SSSPM and SSLRSG models, both of which yielded very low results, had odd shapes (such as jagged edges) or were uninformative (e.g., for r). The model fits to the CPUE series were good, with the exception of the fits to the Shark observer CPUE series in all cases.

When comparing across updated ASPM models, the results from using only fishery-independent vs. fishery-dependent indices presented a spectrum of possible outcomes, with the estimate obtained using all indices falling in the middle, and indicating that spawning stock biomass would be a little under that which would produce MSY and current fishing mortality about 40% above that which would produce MSY. Because the latter estimate made use of all available CPUE information, it is probably the best model to consider in the updated scenario. The baseline models painted a much more optimistic picture, indicating that the resource was above $B_{MSY.}$ Convergence problems when using only the fishery-dependent or fishery-independent indices precluded a comparison with the model that used all indices as with the updated models. The only difference in the data used for the updated vs. baseline models was the catch series, which extended further back (1986 vs. 1981) in the baseline model. As was pointed out in the results section, the fact that only the early Rec CPUE series extended back to 1981 did not seem to be the reason for the large difference between models. It is also interesting to note that runs of the baseline model (including estimated catch for 1981-1985) yielded estimates of fishing rate in 1981-1985 that were very close to the estimate of historic fishing. The estimate of historic fishing was very similar in 5 of the 6 scenarios for blacktip shark.

Except for the very unlikely predictions of the MLE model, results for blacktip shark are more consistent in indicating that the resource is close to MSY levels or even above. Resource status has thus improved since 1998, and summarized results indicated that resource status is at or above B_{MSY} and $F \leq F_{MSY}$, with only some of the age-structured models indicating that $F > F_{MSY}$ (**Figure 76**). No reduction in catch appears needed to maintain the stock at its present condition and even an increase in TAC of 20-50% of the 2000 catch could still maintain the stock at or above B_{MSY} in the long term (**Figure 77**).

4.1. Management Implications and Recommendations

4.1.1. Total Allowable Catch and Minimum Sizes

Although it is difficult to reconcile the results obtained with the multiple stock assessment methods used, the balance of data seems to indicate that a reduction in catches of the large coastal shark complex may be necessary to recover the complex as a whole to estimated B_{MSY}. Given the results for sandbar and blacktip sharks, reductions to allowable catch levels of other species in the complex would appear to be the most appropriate course of action. For sandbar and blacktip sharks the reconciliation process is more difficult because the MLE method and age-structured model were added to the surplus production and simplified delay-difference models for the analyses. For sandbar shark, results were particularly conflicting. After close examination of the range of plausible outcomes, it appears that no further rebuilding may be necessary based on present estimated levels of current biomass, yet a reduction in fishing mortality may be necessary because overfishing still appears to be occurring. For blacktip shark, there does not appear to be a need for reductions in fishing mortality and a small increase in the TAC may also maintain the stock at or above B_{MSY}.

It is unclear, however, how reductions in fishing mortality for the large coastal shark complex should be applied. Estimated recreational catches have been higher than estimated commercial catches since 1996, with the exception of 1998 and 1999, and it appears that the minimum size limit imposed on the recreational sector has been largely ineffective (SB-02-2 and 15), and the reduced bag limit per trip is often not met. Significant reductions in mortality from the recreational sector could be achieved if these regulations were followed. The issue of incidental catches and subsequent discarding of dead large coastal sharks in commercial fisheries must also be considered. Regulations limiting effort in those fisheries or a dead discard allowance could be implemented, but analysis of the expected impacts of such measures, given current stock status information, have not been undertaken. It is unclear whether this potential dead discard allowance should be deducted from the commercial quota or should just be part of the overall TAC. Reduced quota could lead to increased discards of large coastal sharks in those incidental fisheries if they continue to operate unchanged, contrary to the desired reduction in effective fishing mortality.

As recommended in the 1998 SEW Report, every effort should be made to manage on a species-specific basis, because it has become more apparent that individual species are responding differently to exploitation. Risk-neutral management of the large coastal shark complex can result in excessive regulation related to some species and excessive risk of overfishing on others. This assessment thus examined the sandbar and blacktip shark separately as was initially done in 1998. Options for carrying this forth through management were identified in the 1998 SEW Report and included, most notably, the implementation of minimum sizes in both commercial and recreational fisheries. As noted above, minimum size regulations for Atlantic sharks are only in effect for the recreational sector, but do not yet appear effective.

Since the 1998 assessment was conducted, new studies on populations of sharks have shown that most species included in the large coastal shark complex or now classified as prohibited species have low population growth rates (Smith et al. 1998). It has also been shown that for those species, juvenile survival is the vital rate that most affects overall population growth rates, and that fecundity greatly explains the variability in those rates, thus lending additional support to minimum sizes and protection of reproductive females as possibly important management measures (Cortés 2002c). Protection of reproductive females could be achieved through specific time-area closures based on knowledge of the biology of each species, but would undoubtedly not be an easy task.

4.1.2. Prohibited Species

Based in part on the results of the 1998 assessment, NMFS extended the list of prohibited species to include 19 species of sharks: whale, basking, sand tiger, bigeye sand tiger, white, dusky, night, bignose, Galapagos, Caribbean reef, narrowtooth, longfin mako, bigeye thresher, sevengill, sixgill, bigeye sixgill, Caribbean sharpnose, smalltail, and Atlantic angel sharks. These species were identified as highly susceptible to overexploitation, even though basic biological information was (and still is) lacking for many of them, and thus the prohibition on possession was a preventive measure taken to avoid development of directed fisheries for these species. Of these 19 prohibited species, dusky and sand tiger, and to a lesser extent, white and bignose shark, are sharks formerly classified as large coastal that are encountered regularly in longline operations, whereas dusky, white, and Caribbean reef sharks are encountered in recreational operations. The remaining prohibited species, with the exception of longfin mako and bigeye thresher, are encountered rarely in fishing operations.

As reported in the previous subsection, since the 1998 assessment was conducted, new studies on populations of several species of sharks, including the prohibited dusky, white, and Galapagos sharks, have shown that most of the large species of sharks have low population growth rates (Smith et al. 1998) and that their populations are especially susceptible to mortality of the juvenile stage or reproductive potential (Cortés 2002c). The dusky shark is the only prohibited species for which more biological and fishery information has become available and for which an assessment may be possible in the relatively near future.

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Table 1. Catch history of the large coastal shark complex (**updated scenario**). Numbers of fish in thousands.

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Total
1981	16.2	0.9	265			282.1
1982	16.2	0.9	413.9			431
1983	17.5	0.9	746.6			765
1984	23.9	1.3	254.6			279.8
1985	22.2	1.2	365.6			389
1986	54	2.9	426.1	24.9		507.9
1987	104.7	9.7	314.4	70.3		499.1
1988	274.6	11.4	300.6	113.3		699.9
1989	351	10.5	221.1	96.3		678.9
1990	267.5	8	213.2	52.1		540.8
1991	200.2	7.5	293.4	11.3		512.4
1992	215.2	20.9	304.9			541.1
1993	169.4	7.3	249.0		11.3	437
1994	228	8.8	160.9		16.3	414
1995	222.4	5.2	176.3		13.9	417.8
1996	160.6	5.7	188.5		7.6	362.4
1997	130.6	5.6	165.1		8.3	309.6
1998	174.9	4.3	169.8		9.9	358.9
1999	111.5	9.0	91.0		3.8	215.3
2000	111.2	9.4	140.4		4.8	265.8
2001	99.2	9.4	142.0		6.3	256.9

Table 2. Catch history of the sandbar shark (**updated scenario**). Numbers of fish.

Year	Commercial Landings	Recreational catches	Unreported catches	Total
1986	22187	123660	6225	152072
1987	63667	32551	17575	113793
1988	76266	64792	56650	197708
1989	117428	27417	48150	192995
1990	112158	58814	26050	197022
1991	91716	36794	5650	134160
1992	96670	36294		132964
1993	69171	26607		95778
1994	126455	14974		141429
1995	84372	24906		109278
1996	65515	35711		101226
1997	41415	41618		83033
1998	62776	35766		98542
1999	53248	20553		73801
2000	37331	10743		48074
2001	50668	35880		86548

Table 3. Catch history of the blacktip shark (**updated scenario**). Numbers of fish.

Year	Commercial Landings	Recreational catches	Unreported catches	Mexican catches	Total
1986	59173	162402	18675	15642	255892
1987	71392	129551	52725	22346	276014
1988	160991	139806	56650	29050	386497
1989	186947	111368	48150	35754	382219
1990	100112	94136	26050	42458	262756
1991	133868	150794	5650	49161	339473
1992	176108	157663		55865	389636
1993	150584	109057		62569	322210
1994	198413	66106		62569	327088
1995	142234	59892		62569	264695
1996	97326	79753		62569	239648
1997	91974	70963		62569	225506
1998	103012	82310		62569	247891
1999	56133	34962		62569	153664
2000	51354	74055		62569	187978
2001	43157	48848		62569	154574

Table 4. Catch history of the large coastal shark complex (**baseline scenario**). Numbers of fish in thousands.

Year	Commercial landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom Longline discards	Mexican catches	Menhaden fishery discards	Total
1981	16.2	0.9	265.0		0.9	119.971	25.1	428.1
1982	16.2	0.9	413.9		0.9	81.913	25.1	538.9
1983	17.5	0.9	746.6		1.0	85.437	25.1	876.5
1984	23.9	1.3	254.6		1.4	120.684	25.1	426.9
1985	22.2	1.2	365.6		1.3	87.748	25.1	503.1
1986	54.0	2.9	426.1	24.9	3.1	81.835	25.1	617.9
1987	104.7	9.7	314.4	70.3	5.9	80.160	25.1	610.3
1988	274.6	11.4	300.6	113.3	15.5	89.290	25.1	829.8
1989	351.0	10.5	221.1	96.3	19.9	105.562	25.1	829.4
1990	267.5	8.0	213.2	52.1	15.1	122.220	25.1	703.3
1991	200.2	7.5	293.4	11.3	11.3	95.695	25.1	644.5
1992	215.2	20.9	304.9		12.2	103.366	25.1	681.6
1993	169.4	7.3	249.0		11.3	119.820	25.1	581.9
1994	228.0	8.8	160.9		16.3	110.734	26.2	550.9
1995	222.4	5.2	176.3		13.9	95.996	24.0	537.8
1996	160.6	5.7	188.5		7.6	106.057	25.1	493.6
1997	130.6	5.6	165.1		8.3	83.051	25.1	417.8
1998	174.9	4.3	169.8		9.9	74.136	25.1	458.1
1999	111.5	9.0	91.0		3.8	57.061	25.1	297.5
2000	111.2	9.4	140.4		4.8	52.057	25.1	343.0
2001	99.2	9.4	142.0		6.3	52.057	25.1	334.1

Table 5. Catch history of the sandbar shark (**baseline scenario**).
Numbers of fish.

Year	Commercial Landings	Recreational catches	Unreported catches	Menhaden fish. Bycatch	Mexican catches	Total
1981	6640	128841		465	10065	146012
1982	6640	32955		465	11822	51882
1983	7173	415722		465	11126	434486
1984	9797	56426		465	11708	78396
1985	9100	67396		465	7910	84871
1986	22187	123660	6225	465	9368	161905
1987	63667	32551	17575	465	6962	121220
1988	76266	64792	56650	465	9142	207315
1989	117428	27417	48150	465	8346	201806
1990	112158	58814	26050	465	10738	208225
1991	91716	36794	5650	465	9063	143688
1992	96670	36294		465	9675	143104
1993	69171	26607		465	9080	105323
1994	126455	14974		486	8762	150677
1995	84372	24906		445	9892	119615
1996	65515	35711		465	10732	112423
1997	41415	41618		465	8364	91862
1998	62776	35766		465	7208	106215
1999	53248	20553		465	7976	82242
2000	37331	10743		465	7051	55590
2001	50668	35880		465	7051	94064

Table 6. Catch history of the blacktip shark (**baseline scenario**).
Numbers of fish.

Year	Commercial Landings	Recreational catches	Unreported catches	Mexican catches	Menhaden fish. Bycatch	Total
1981	7812	54875		109906	11700	184293
1982	7812	70665		70091	11700	160268
1983	8439	33633		74311	11700	128083
1984	11525	37839		108976	11700	170040
1985	10705	97425		79838	11700	199668
1986	59173	162402	18675	72467	11700	324417
1987	71392	129551	52725	73198	11700	338566
1988	160991	139806	56650	80148	11700	449295
1989	186947	111368	48150	97216	11700	455381
1990	100112	94136	26050	111482	11700	343480
1991	133868	150794	5650	86632	11700	388644
1992	176108	157663		93691	11700	439162
1993	150584	109057		110740	11700	382081
1994	198413	66106		101972	12200	378691
1995	142234	59892		86104	11200	299430
1996	97326	79753		95325	11700	284104
1997	91974	70963		74687	11700	249324
1998	103012	82310		66928	11700	263950
1999	56133	34962		49085	11700	151880
2000	51354	74055		45006	11700	182115
2001	43157	48848		45006	11700	148711

Table 7. Catch history of the large coastal shark complex (**alternative scenario**). Numbers of fish in thousands.

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Menhaden fishery discards	Total
1960	2.0						2.0
1961	9.0						9.0
1962	1.9						1.9
1963	2.1		3.5				5.6
1964	2.1		1.8				3.9
1965	5.9		6.1				12.0
1966	3.5		9.2				12.7
1967	15.3		9.2				24.5
1968	1.5		6.1				7.6
1969	1.6		7.6				9.2
1970	1.5	4.3	8.8				14.6
1971	1.0	4.3	10.1				15.4
1972	1.4	4.3	24.6				30.3
1973	5.0	4.3	34.7				44.0
1974	2.0	4.3	32.5				38.8
1975	3.7	4.3	32.0				40.0
1976	3.8	4.3	46.5				54.6
1977	5.1	4.3	62.7				72.1
1978	7.1	10.0	70.0				87.1
1979	4.3	10.0	65.8				80.1
1980	12.0	10.0	67.7				89.7
1981	24.3	10.0	265		1.4	25.1	325.8
1982	24.3	10.0	413.9		1.4	25.1	474.7
1983	26.2	10.0	324.6		1.5	25.1	387.4
1984	35.8	10.0	254.6		2.0	25.1	327.5
1985	33.3	10.0	365.6		1.9	25.1	435.9
1986	108	10.0	426.1	24.9	6.1	25.1	600.2
1987	209.4	9.7	314.4	70.3	11.9	25.1	640.8
1988	549.2	11.4	300.6	113.3	31.1	25.1	1030.7
1989	702.0	10.5	221.1	96.3	39.7	25.1	1094.7
1990	535.0	8.0	213.2	52.1	30.3	25.1	863.7
1991	400.4	7.5	293.4	11.3	22.7	25.1	760.4
1992	430.4	20.9	304.9		24.4	25.1	805.7
1993	254.1	7.3	249.0		14.4	25.1	549.9
1994	228.0	8.8	160.9		16.3	26.2	440.2
1995	222.4	5.2	176.3		13.9	24.0	441.8

Table 7 (continued). Catch history of the large coastal shark complex (**alternative scenario**). Numbers of fish in thousands.

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Menhaden fishery discards	Total
1996	160.6	5.7	188.5		7.6	25.1	387.5
1997	130.6	5.6	165.1		8.3	25.1	334.7
1998	174.9	4.3	169.8		9.9	25.1	384.0
1999	111.5	9.0	91.0		3.8	25.1	240.4
2000	111.2	9.4	140.4		4.8	25.1	290.9
2001	99.2	9.4	142.0		6.3	25.1	282

Table 8. Modified alternative catch history of the large coastal shark complex incorporating adjustments to the menhaden fishery discards based on historical estimates of effort in the Gulf of Mexico fleet. See text for a full explanation. Numbers of fish in thousands.

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Menhaden fishery discards	Total
1960	2.0					36.6	38.6
1961	9.0					36.6	45.6
1962	1.9					36.6	38.5
1963	2.1		3.5			36.6	42.2
1964	2.1		1.8			36.6	40.5
1965	5.9		6.1			40.9	52.9
1966	3.5		9.2			43.2	55.9
1967	15.3		9.2			39.9	64.4
1968	1.5		6.1			36.6	44.2
1969	1.6		7.6			35.1	44.3
1970	1.5	4.3	8.8			35.6	50.2
1971	1.0	4.3	10.1			39.9	55.3
1972	1.4	4.3	24.6			35.1	65.4
1973	5.0	4.3	34.7			30.9	74.9
1974	2.0	4.3	32.5			33.4	72.2
1975	3.7	4.3	32.0			36.6	76.6
1976	3.8	4.3	46.5			38.4	93.0
1977	5.1	4.3	62.7			37.7	109.8
1978	7.1	10.0	70.0			37.7	124.8
1979	4.3	10.0	65.8			36.6	116.7
1980	12.0	10.0	67.7			37.1	126.8
1981	24.3	10.0	265		1.4	37.7	338.3
1982	24.3	10.0	413.9		1.4	38.4	488.0
1983	26.2	10.0	324.6		1.5	37.9	400.2
1984	35.8	10.0	254.6		2.0	37.9	340.3
1985	33.3	10.0	365.6		1.9	34.1	444.9
1986	108	10.0	426.1	24.9	6.1	33.9	609.0
1987	209.4	9.7	314.4	70.3	11.9	35.1	650.8
1988	549.2	11.4	300.6	113.3	31.1	34.1	1039.7
1989	702.0	10.5	221.1	96.3	39.7	36.1	1105.8
1990	535.0	8.0	213.2	52.1	30.3	35.1	873.7
1991	400.4	7.5	293.4	11.3	22.7	27.1	762.4
1992	430.4	20.9	304.9		24.4	23.8	804.4
1993	254.1	7.3	249.0		14.4	24.3	549.1

Table 8 (continued). Modified alternative catch history of the large coastal shark complex.

Year	Commercial Landings	Pelagic longline discards	Recreational catches	Unreported catches	Bottom longline discards	Menhaden fishery discards	Total
1994	228.0	8.8	160.9		16.3	26.2	440.2
1995	222.4	5.2	176.3		13.9	24.0	441.8
1996	160.6	5.7	188.5		7.6	23.8	386.2
1997	130.6	5.6	165.1		8.3	24.3	333.9
1998	174.9	4.3	169.8		9.9	23.3	382.2
1999	111.5	9.0	91.0		3.8	25.9	241.2
2000	111.2	9.4	140.4		4.8	22.1	287.9
2001	99.2	9.4	142.0		6.3	20.6	277.5

Table 9. Prior probability distributions of parameters used in the Bayesian Surplus Production Model (SPM) with the SIR algorithm, the Bayesian state-space surplus production model (SSSPM) with the MCMC algorithm, and the Bayesian state-space lagged recruitment, survival, and growth model (SSLRSG) with the MCMC algorithm. K is carrying capacity (or B_0, virgin biomass, for the LRSG model), r is the intrinsic rate of population increase, C_0 is annual catch from 1974 to 1980, N_{1974}/K is the ratio of abundance in 1974 to carrying capacity, q is the catchability coefficient, σ^2 is observation error variance in the SPM (SIR) model and process error variance in both state-space models, τ^2 is observation error variance in both state-space models, z is the Beverton-Holt steepness parameter, and s is annual survivorship.

Grouping/ Model	**K**	**r**	**C_0**	**N_{1974}/K**	**q**	**σ^2**	**τ^2**	**z**	s
SPM (SIR)									
LCS complex	Uniform[1] (10^5-10^9)	Lognormal (0.113,0.7,0.001,2.0)	Lognormal (487.3,0.51,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	Uniform on log[2]	Uniform on log	N/A	N/A	N/A
Sandbar	Uniform (10^5-10^9)	Lognormal (0.117,0.7,0.001,2.0)	Lognormal (135.9,0.53,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	Uniform on log	Uniform on log	N/A	N/A	N/A
Blacktip	Uniform (10^5-10^9)	Lognormal (0.136,0.7,0.001,2.0)	Lognormal (303.8,0.43,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	Uniform on log	Uniform on log	N/A	N/A	N/A
SSSPM (MCMC)									
LCS complex	Uniform (10^5-10^9)	Lognormal (0.113,0.7,0.001,2.0)	Lognormal (487.3,0.51,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	MLE[3]	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)	N/A	N/A
Sandbar	Uniform (10^5-10^9)	Lognormal (0.117,0.7,0.001,2.0)	Lognormal (135.9,0.53,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)	N/A	N/A
Blacktip	Uniform (10^5-10^9)	Lognormal (0.136,0.7,0.001,2.0)	Lognormal (303.8,0.43,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)	N/A	N/A
SSLRSG (MCMC)									
LCS complex	Uniform (10^5-10^9)	N/A	Lognormal (487.3,0.51,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)	Uniform (0.2-0.9)	Uniform (0.60-0.95)
Sandbar	Uniform (10^5-10^9)	N/A	Lognormal (135.9,0.53,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)	Uniform (0.2-0.9)	Uniform (0.70-1.0)
Blacktip	Uniform (10^5-10^9)	N/A	Lognormal (303.8,0.43,10^3,5x10^6)	Lognormal (1,0.2,0.1,1.5)	MLE	Inverse gamma (0.04-0.08)	Inverse gamma (0.05-0.15)	Uniform (0.2-0.9)	Uniform (0.65-0.95)

[1] Values in parentheses are lower and upper bounds (uniform distribution), mean, SD, lower bound, and upper bound (lognormal distribution), 10% and 90% quantiles (inverse gamma distribution); [2] Priors for q and σ^2 were given a uniform distribution on a log scale, but were integrated from the joint posterior distribution using the method described by Walters and Ludwig (1994); [3] The maximum likelihood estimate of q for each CPUE series was used instead of a prior for q.

Table 10. Summary of input for Sandbar Updated MLE model.

Year	Recreational Input			Commercial Input			
	Est(Catch)	Var(Catch)	Effort (# trips)	Ave. Weight	Var(Ave. Weight)	Yield	Effort (# sets)
1994	14974	9128423	59949559	37.153	165.09	4691470	18716
1995	24906	30091163	58561520	35.689	264.11	3012065	20438
1996	35711	68502117	56897493	30.586	247.94	2004759	25335
1997	41618	80581051	61861764	30.963	282.03	1283871	16242
1998	35766	1.34E+08	54789232	23.846	255.52	1494078	23736
1999	20553	32134015	50912118	32.469	392.59	1730570	12032
2000	10743	29620187	69280265	41.207	141.57	1538020	13751

Table 11. Summary of input for Sandbar Baseline MLE model.

Year	Recreational Input			Commercial Input			
	Est(Catch)	Var(Catch)	Effort (# trips)	Ave. Weight	Var(Ave. Weight)	Yield	Effort (# sets)
1994	23736	9128423	59949559	37.153	165.09	4691470	18716
1995	34798	30091163	58561520	35.689	264.11	3012065	20438
1996	46443	68502117	56897493	30.586	247.94	2004759	25335
1997	49982	80581051	61861764	30.963	282.03	1283871	16242
1998	42974	1.34E+08	54789232	23.846	255.52	1494078	23736
1999	28529	32134015	50912118	32.469	392.59	1730570	12032
2000	17794	29620187	69280265	41.207	141.57	1538020	13751

Table 12. Summary of input for Blacktip Updated MLE model.

Year	Recreational Input			Commercial Input			
	Est(Catch)	Var(Catch)	Effort (# trips)	Ave. Weight	Var(Ave. Weight)	Yield	Effort (# sets)
1994	128675	63100920	59949559	19.317	108.14	3829364	18716
1995	122461	1.01E+08	58561520	20.52	125	2915797	20438
1996	142322	1.4E+08	56897493	21.815	112.55	2121714	25335
1997	133532	96211913	61861764	23.574	46.58	2170597	16242
1998	144879	1.32E+08	54789232	25.463	98.75	2626806	23736
1999	97531	22350579	50912118	29.369	70.62	1650319	12032
2000	136624	71962859	69280265	32.781	44.38	1684420	13751

Table 13. Summary of input for Blacktip Baseline MLE model.

Year	Recreational Input			Commercial Input			
	Est(Catch)	Var(Catch)	Effort (# trips)	Ave. Weight	Var(Ave. Weight)	Yield	Effort (# sets)
1994	168078	63100920	59949559	19.317	108.14	3829364	18716
1995	145996	1.01E+08	58561520	20.52	125	2915797	20438
1996	175078	1.4E+08	56897493	21.815	112.55	2121714	25335
1997	145650	96211913	61861764	23.574	46.58	2170597	16242
1998	149238	1.32E+08	54789232	25.463	98.75	2626806	23736
1999	84047	22350579	50912118	29.369	70.62	1650319	12032
2000	119061	71962859	69280265	32.781	44.38	1684420	13751

Table 14. Selectivity functions for sandbar shark age-structured models.

Age	all	0-1	2-7	8-12	13-max	1-12
1	0.54	0.99	0.01	0.00	0.00	1.00
2	0.59	0.05	0.28	0.00	0.00	1.00
3	0.64	0.00	0.87	0.03	0.00	1.00
4	0.68	0.00	0.95	0.11	0.00	1.00
5	0.72	0.00	0.58	0.29	0.00	1.00
6	0.76	0.00	0.25	0.52	0.00	1.00
7	0.80	0.00	0.08	0.76	0.00	1.00
8	0.83	0.00	0.02	0.93	0.00	1.00
9	0.85	0.00	0.01	1.00	0.00	1.00
10	0.88	0.00	0.00	0.97	0.00	1.00
11	0.90	0.00	0.00	0.87	0.00	1.00
12	0.91	0.00	0.00	0.73	0.08	0.92
13	0.93	0.00	0.00	0.57	0.92	0.08
14	0.94	0.00	0.00	0.43	1.00	0.00
15	0.95	0.00	0.00	0.31	1.00	0.00
16	0.96	0.00	0.00	0.22	1.00	0.00
17	0.97	0.00	0.00	0.15	1.00	0.00
18	0.97	0.00	0.00	0.10	1.00	0.00

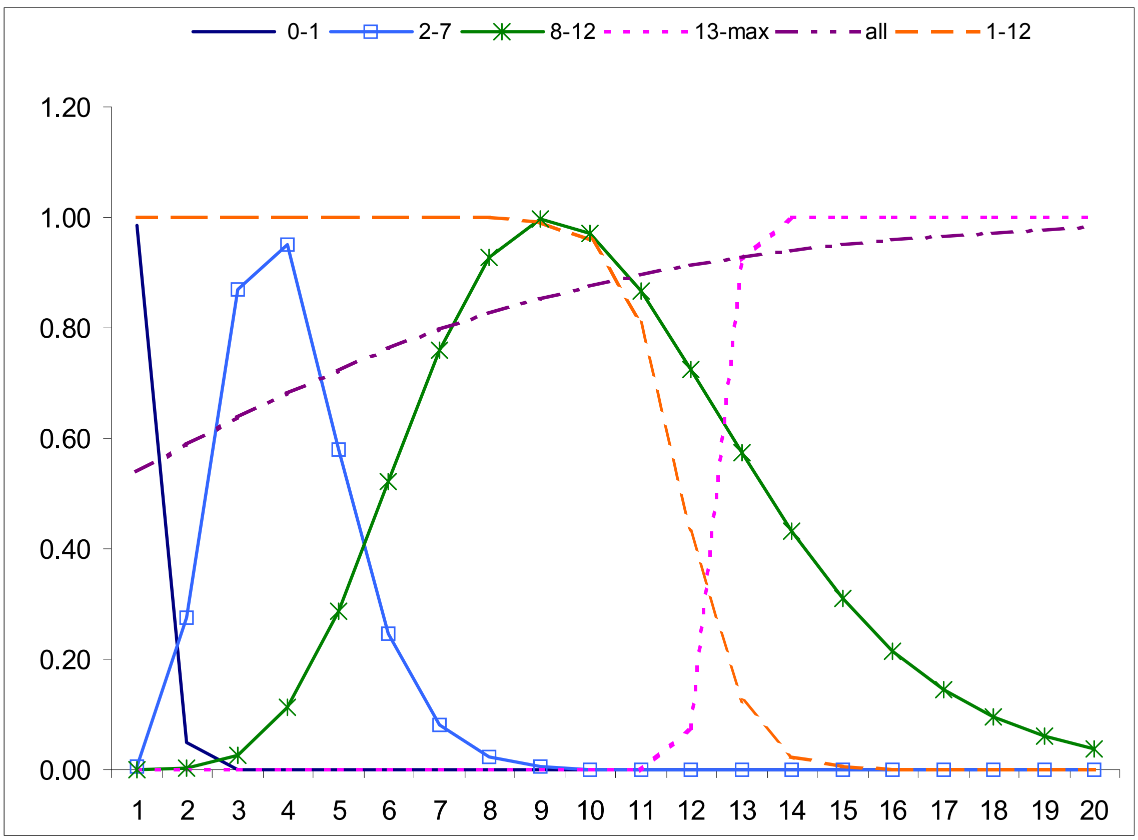


Table 15. Selectivity functions for blacktip shark age-structured models. The recreational (REC) function was a Gamma distribution (1.699, 0.472), commercial (COMM) was a logistic function (0.8825, 2.6276), age-0 was a Gamma distribution (8.2, 0.115), and age 1-5 was a logistic function (25, -4.65).

Age	REC	COMM	AGE 0	AGE 1-5
0	0.00	0.05	0.00	1.00
1	0.96	0.14	0.99	1.00
2	0.37	0.33	0.05	1.00
3	0.09	0.60	0.00	1.00
4	0.02	0.83	0.00	1.00
5	0.00	0.94	0.00	0.85
6	0.00	0.98	0.00	0.05
7	0.00	0.99	0.00	0.00
8	0.00	1.00	0.00	0.00
9	0.00	1.00	0.00	0.00
10	0.00	1.00	0.00	0.00
11	0.00	1.00	0.00	0.00
12	0.00	1.00	0.00	0.00
13	0.00	1.00	0.00	0.00
14	0.00	1.00	0.00	0.00

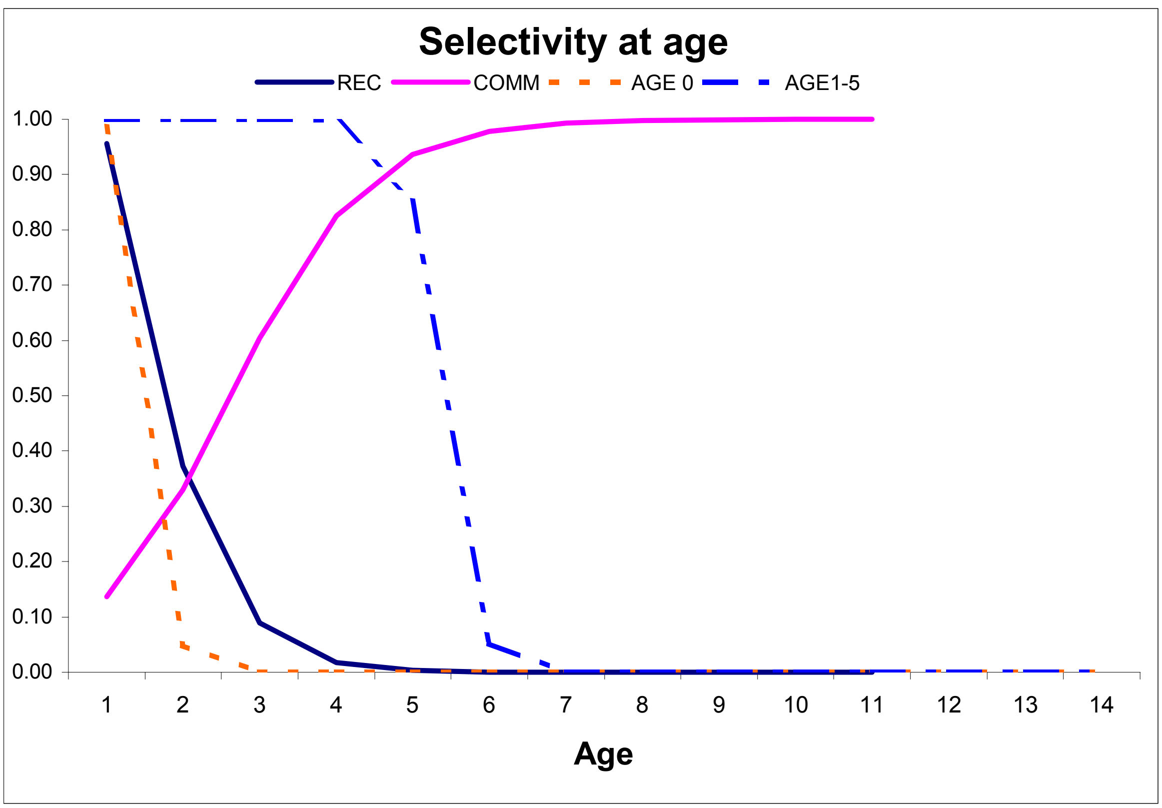


Table 16. Convergence diagnostics for the Bayesian surplus production model analyses using the SIR algorithm. See text for an explanation of weighting methods. The variance expansion factor is the multiplier applied to the variance estimated from the Hessian matrix. The last column gives the diagnostic of the appropriateness of the importance function, defined as the ratio of the CV of the weights (importance ratios) to the CV of the product of the likelihood function and the prior distribution. Values<1 indicate that the algorithm has converged adequately; high values (>10) indicate lack of convergence (SB-02-25).

Scenario	Stock grouping	Weighting method	Importance function	Variance expansion factor	CV(w)/ CV(L*p)
Updated	Large coastal shark	Equal weights	Multivariate t	2	0.91
Updated	Large coastal shark	Equal weights	Priors	2	1.71
Updated	Large coastal shark	Inverse variance	Priors	2	2.25
Updated	Large coastal shark	MLE of σ^2 for each series	Priors	2	0.74
Updated	Large coastal shark	σ as a free parameter	Priors	2	0.80
Updated	Large coastal shark	input σ^2 * scale parameter	Priors	2	0.82
Updated	Large coastal shark	L/inputted CV	Priors	2	---
Updated	Large coastal shark	input $\sigma^2 + \sigma^2$ for each series	Priors	2	0.68
Updated	Large coastal shark	inverse $\sigma^2 + \sigma^2$ for each year	Priors	2	---
Updated	Large coastal shark	input σ^2 + scale parameter	Priors	2	0.28
Updated	Large coastal shark	Equal weights, 1 σ	Priors	2	0.80
Updated	Sandbar shark	Equal weights	Priors	2	5.80
Updated	Sandbar shark	Inverse variance	Multivariate t	2	2.65
Updated	Blacktip shark	Equal weights	Multivariate t	1	2.24
Updated	Blacktip shark	Inverse variance	Multivariate t	1	1.82
Baseline	Large coastal shark	Equal weights	Multivariate t	2	0.86
Baseline	Large coastal shark	Inverse variance	Priors	2	1.00
Baseline	Sandbar shark	Equal weights	Priors	2	2.05
Baseline	Sandbar shark	Inverse variance	Priors	2	3.12
Baseline	Blacktip shark	Equal weights	Priors	1	0.46

Table 16 (continued).

Scenario	Stock grouping	Weighting method	Importance function	Variance expansion factor	CV(w)/ CV(L*p)
Baseline	Blacktip shark	Inverse variance	Priors	1	0.65
Alternative	Large coastal shark	Equal weights	Multivariate t	2	0.79
Baseline; F-D series only	Large coastal shark	Equal weights	Multivariate t	2	0.91
Baseline; F-D series only	Large coastal shark	Inverse variance	Priors	2	0.88
Baseline; F-D series + BLL Logs ST	Large coastal shark	Equal weights	Priors	2	0.81
Baseline; F-D series only	Sandbar shark	Equal weights	Multivariate t	2	0.34
Baseline; F-D series only	Sandbar shark	Inverse variance	Multivariate t	2	1.55
Baseline; F-D series only+Shk Obs+LPS	Sandbar shark	Equal weights	Multivariate t	2	0.89
Baseline; F-D series only	Blacktip shark	Equal weights	Priors	1	0.38
Baseline; F-D series only	Blacktip shark	Inverse variance	Multivariate t	1	23.35
Baseline; F-D series only + Driftnet Obs	Blacktip shark	Equal weights	Priors	1	0.32
Baseline; F-I series only	Large coastal shark	Equal weights	Multivariate t	2	0.76
Baseline; F-I series only	Large coastal shark	Inverse variance	Priors	2	0.41
Baseline; F-I series only	Sandbar shark	Equal weights	Priors	2	1.26
Baseline; F-I series only	Sandbar shark	Inverse variance	Priors	2	0.69
Baseline; F-I series only	Blacktip shark	Equal weights	Multivariate t	1	1.70
Baseline; F-I series only	Blacktip shark	Inverse variance	Multivariate t	1	1.29
Baseline; F-I series + SC LL	Blacktip shark	Equal weights	Multivariate t	2	0.80
Baseline; 21 series (+BLL Logs ST)	Large coastal shark	Equal weights	Multivariate t	2	0.86
Baseline; 21 series (+BLL Logs ST)	Large coastal shark	Inverse variance	Priors	2	0.52
Baseline; 11 series (+Shark Observer)	Sandbar shark	Equal weights	Priors	2	2.25
Baseline; 11 series (+Shark Observer)	Sandbar shark	Inverse variance	Priors	2	3.82

Table 16 (continued).

Scenario	Stock grouping	Weighting method	Importance function	Variance expansion factor	CV(w)/ CV(L*p)
Baseline; 11 series (+LPS)	Sandbar shark	Equal weights	Priors	2	1.50
Baseline; 11 series (+LPS)	Sandbar shark	Inverse variance	Multivariate t	2	1.11
Baseline; 12 series (+Shark Obs+LPS)	Sandbar shark	Equal weights	Priors	2	1.72
Baseline; 12 series (+Shark Obs+LPS)	Sandbar shark	Inverse variance	Multivariate t	2	1.06
Baseline; 9 series (+Driftnet Observer)	Blacktip shark	Equal weights	Priors	1	0.36
Baseline; 9 series (+Observer)	Blacktip shark	Inverse variance	Multivariate t	1	56.22
Baseline; 9 series (+SC LL)	Blacktip shark	Equal weights	Multivariate t	1	2.76
Baseline; 9 series (+SC LL)	Blacktip shark	Inverse variance	Multivariate t	1	1.71
Baseline; 10 series (+Driftnet Obs+SCLL)	Blacktip shark	Equal weights	Priors	1	0.34
Baseline; 10 series (+Driftnet Obs+SCLL)	Blacktip shark	Inverse variance	Multivariate t	2	0.29
Alternative (menhaden discards modified)	Large coastal shark	Equal weights	Multivariate t	2	0.79

Table 17. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (updated scenario)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those reported in the 2002 sensitivity analysis using equal weights and the same form of the model (Cortés 2002a), which included data up to 1997 only. Predictions of alternative harvesting policies from the two forms of the model are also included.

	Cortes (2002a)		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	9474	0.20	8939	0.39	3666	0.16
r	0.07	0.72	0.16	0.71	0.48	0.16
C_0	373	0.41	369	0.48	178	0.39
N_{cur}[1]	2112	0.47	3413	0.52	2139	0.16
N_{cur}/K	0.22	0.37	0.39	0.29	0.59	0.13
MSC	160	0.50	285	0.32	434	0.04
F_{cur}/F_{msy}	---	---	1.53	0.71	0.52	0.19

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[2]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[3]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.67	1.34	0.77	1	0.99	1.97	1	1
(2011)	0.5	0.55	1.11	0.58	0.88	0.9	1.80	1	1
	0.8	0.46	0.93	0.43	0.66	0.84	1.67	1	1
	1.0	0.40	0.80	0.33	0.48	0.79	1.57	1	1
	1.2	0.33	0.66	0.23	0.31	0.73	1.46	1	1
	1.5	0.22	0.45	0.11	0.08	0.62	1.24	0.96	0.88
20-year	0	0.82	1.64	0.93	1	1	2	1	1
(2021)	0.5	0.64	1.29	0.72	0.89	0.92	1.83	1	1
	0.8	0.50	1	0.53	0.66	0.86	1.71	1	1
	1.0	0.39	0.77	0.40	0.48	0.81	1.62	1	1
	1.2	0.27	0.55	0.27	0.30	0.75	1.50	1	1
	1.5	0.13	0.26	0.10	0.07	0.63	1.25	0.97	0.87
30-year	0	0.89	1.79	0.97	1	1	2	1	1
(2031)	0.5	0.69	1.38	0.79	0.89	0.92	1.83	1	1
	0.8	0.51	1.02	0.58	0.66	0.86	1.71	1	1
	1.0	0.38	0.75	0.44	0.48	0.81	1.62	1	1
	1.2	0.25	0.50	0.29	0.30	0.75	1.51	1	1
	1.5	0.10	0.20	0.10	0.07	0.63	1.25	0.97	0.87

[1] $_{cur}$ = 1998 in Cortes (2002a) and 2001 in all present analyses

[2] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch

[3] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 18. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (updated scenario)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those reported in the 2002 sensitivity analysis using equal weights and the same form of the model (Cortés 2002a), which included data up to 1997 only. Predictions of alternative harvesting policies from the two forms of the model are also included.

	Cortes (2002a)		**Equal weighting**		**Inverse σ^2 weighting**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	3296	0.42	3019	0.55	3055	0.59
r	0.10	0.82	0.23	0.98	0.24	0.88
C_0	161	0.57	167	0.64	175	0.77
N_{cur}[1]	1011	0.69	1402	0.59	1447	0.58
N_{cur}/K	0.31	0.45	0.50	0.33	0.52	0.32
MSC	71	0.48	110	0.36	120	0.37
F_{cur}/F_{msy}	---	---	1.08	0.76	0.90	0.67

		Equal weighting				**Inverse σ^2 weighting**			
Horizon	**TAC**[2]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[3]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.77	1.53	0.89	1	0.79	1.59	0.93	1
(2011)	0.5	0.72	1.44	0.84	0.99	0.75	1.49	0.89	1
	0.8	0.68	1.36	0.79	0.96	0.71	1.42	0.85	0.98
	1.0	0.66	1.31	0.76	0.93	0.69	1.37	0.83	0.96
	1.2	0.63	1.26	0.73	0.88	0.66	1.32	0.80	0.92
	1.5	0.59	1.17	0.67	0.79	0.62	1.24	0.74	0.86
20-year	0	0.88	1.77	0.97	1	0.90	1.81	0.98	1
(2021)	0.5	0.81	1.63	0.93	0.99	0.84	1.68	0.96	1
	0.8	0.76	1.53	0.89	0.97	0.80	1.59	0.93	0.98
	1.0	0.73	1.45	0.85	0.93	0.76	1.53	0.91	0.96
	1.2	0.69	1.38	0.81	0.89	0.73	1.46	0.88	0.93
	1.5	0.62	1.25	0.73	0.79	0.67	1.34	0.82	0.86
30-year	0	0.93	1.87	0.99	1	0.95	1.90	0.99	1
(2031)	0.5	0.86	1.72	0.96	1	0.88	1.76	0.98	1
	0.8	0.80	1.61	0.92	0.97	0.83	1.67	0.96	0.98
	1.0	0.76	1.52	0.88	0.93	0.80	1.60	0.93	0.96
	1.2	0.72	1.43	0.84	0.89	0.76	1.52	0.90	0.93
	1.5	0.64	1.28	0.76	0.79	0.69	1.38	0.84	0.86

[1] cur = 1998 in Cortes (2002a) and 2001 in all present analyses
[2] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[3] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 19. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (updated scenario)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those reported in the 2002 sensitivity analysis using equal weights and the same form of the model (Cortés 2002a), which included data up to 1997 only. Predictions of alternative harvesting policies from the two forms of the model are also included.

	Cortes (2002a)		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	12631	0.44	10834	0.38	10698	0.40
r	0.18	0.81	0.18	0.81	0.19	0.76
C_0	308	0.41	298	0.41	309	0.41
N_{cur}[1]	9746	0.53	8034	0.47	8108	0.47
N_{cur}/K	0.74	0.22	0.73	0.24	0.74	0.22
MSC	493	0.81	426	0.78	451	0.73
F_{cur}/F_{msy}	---	---	0.48	1.19	0.41	1.03

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[2]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[3]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.86	1.72	0.97	1	0.89	1.77	0.98	1
(2011)	0.5	0.80	1.61	0.93	0.97	0.83	1.66	0.96	0.98
	0.8	0.76	1.53	0.89	0.88	0.79	1.59	0.94	0.93
	1.0	0.74	1.47	0.87	0.78	0.77	1.54	0.92	0.83
	1.2	0.71	1.42	0.84	0.54	0.74	1.48	0.89	0.63
	1.5	0.67	1.33	0.80	0.07	0.70	1.39	0.85	0.10
20-year	0	0.92	1.85	0.99	1	0.94	1.89	1	1
(2021)	0.5	0.84	1.68	0.95	0.97	0.87	1.73	0.98	0.98
	0.8	0.78	1.56	0.90	0.88	0.81	1.63	0.95	0.93
	1.0	0.74	1.47	0.86	0.77	0.77	1.55	0.91	0.83
	1.2	0.69	1.38	0.82	0.53	0.73	1.46	0.87	0.61
	1.5	0.62	1.25	0.74	0.06	0.66	1.33	0.80	0.09
30-year	0	0.96	1.91	1	1	0.97	1.94	1	1
(2031)	0.5	0.86	1.72	0.96	0.97	0.88	1.77	0.98	0.98
	0.8	0.79	1.57	0.91	0.88	0.82	1.64	0.95	0.93
	1.0	0.73	1.47	0.86	0.77	0.77	1.55	0.91	0.83
	1.2	0.68	1.35	0.80	0.53	0.72	1.44	0.86	0.61
	1.5	0.59	1.19	0.71	0.06	0.64	1.28	0.77	0.09

[1] $_{cur}$ = 1998 in Cortes (2002a) and 2001 in all present analyses
[2] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[3] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 20. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (baseline scenario)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those reported in the 2002 sensitivity analysis using equal weights and the same form of the model (Cortés 2002a), which included data up to 1997 only. Predictions of alternative harvesting policies from the two forms of the model are also included.

	Cortes (2002a)		**Equal weighting**		**Inverse σ^2 weighting**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	9474	0.20	12229	0.34	11130	0.03
r	0.07	0.72	0.13	0.73	0.04	0.65
C_0	373	0.41	418	0.51	260	1.87
N_{cur}[1]	2112	0.47	4315	0.51	1552	0.05
N_{cur}/K	0.22	0.37	0.35	0.30	0.14	0.17
MSC	160	0.50	315	0.36	100	0.24
F_{cur}/F_{msy}	---	---	2.04	0.73	12.12	5.29

		Equal weighting				**Inverse σ^2 weighting**			
Horizon	**TAC**[2]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[3]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.59	1.19	0.65	1	0.17	0.34	0	1
(2011)	0.5	0.47	0.94	0.41	0.78	0	0.01	0	0
	0.8	0.38	0.75	0.27	0.48	0.01	0.03	0	0
	1.0	0.31	0.62	0.18	0.29	0.01	0.03	0	0
	1.2	0.24	0.49	0.12	0.15	0.01	0.03	0	0
	1.5	0.16	0.31	0.05	0.02	0.01	0.02	0	0
20-year	0	0.76	1.51	0.87	1	0.22	0.45	0	1
(2021)	0.5	0.55	1.09	0.58	0.79	0	0.01	0	0
	0.8	0.38	0.75	0.36	0.48	0.01	0.03	0	0
	1.0	0.26	0.53	0.24	0.29	0.01	0.03	0	0
	1.2	0.17	0.34	0.13	0.15	0.01	0.03	0	0
	1.5	0.07	0.14	0.04	0.02	0.01	0.02	0	0
30-year	0	0.85	1.69	0.94	1	0.29	0.58	0	1
(2031)	0.5	0.59	1.18	0.65	0.80	0	0.01	0	0
	0.8	0.37	0.75	0.41	0.48	0.01	0.03	0	0
	1.0	0.24	0.49	0.26	0.29	0.01	0.03	0	0
	1.2	0.14	0.28	0.14	0.15	0.01	0.03	0	0
	1.5	0.05	0.10	0.03	0.02	0.01	0.02	0	0

[1] $_{cur}$ = 1998 in Cortes (2002a) and 2001 in all present analyses
[2] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[3] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 21. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (baseline scenario)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those reported in the 2002 sensitivity analysis using equal weights and the same form of the model (Cortés 2002a), which included data up to 1997 only. Predictions of alternative harvesting policies from the two forms of the model are also included.

	Cortes (2002a)		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	3296	0.42	2872	0.43	2500	0.48
r	0.10	0.82	0.19	0.74	0.25	0.67
C_0	161	0.57	113	0.52	89	0.48
N_{cur}[1]	1011	0.69	1428	0.52	1349	0.53
N_{cur}/K	0.31	0.45	0.50	0.27	0.55	0.23
MSC	71	0.48	105	0.31	115	0.26
F_{cur}/F_{msy}	---	---	1.16	0.74	0.90	0.65

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[2]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[3]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.78	1.55	0.92	1	0.84	1.69	0.97	1
(2011)	0.5	0.72	1.43	0.85	0.99	0.79	1.57	0.93	1
	0.8	0.67	1.35	0.80	0.95	0.74	1.49	0.90	0.98
	1.0	0.64	1.29	0.76	0.90	0.71	1.43	0.87	0.95
	1.2	0.61	1.22	0.72	0.83	0.68	1.36	0.84	0.91
	1.5	0.56	1.12	0.64	0.71	0.63	1.26	0.79	0.83
20-year	0	0.89	1.78	0.98	1	0.93	1.87	0.99	1
(2021)	0.5	0.81	1.62	0.94	0.99	0.86	1.72	0.97	1
	0.8	0.75	1.49	0.88	0.95	0.81	1.61	0.94	0.98
	1.0	0.70	1.4	0.83	0.91	0.77	1.54	0.92	0.96
	1.2	0.65	1.31	0.77	0.84	0.73	1.45	0.88	0.92
	1.5	0.57	1.14	0.68	0.71	0.66	1.31	0.81	0.83
30-year	0	0.94	1.88	0.99	1	0.97	1.93	1	1
(2031)	0.5	0.85	1.70	0.96	0.99	0.89	1.78	0.98	1
	0.8	0.78	1.56	0.91	0.96	0.83	1.67	0.96	0.98
	1.0	0.73	1.46	0.86	0.91	0.79	1.58	0.93	0.96
	1.2	0.67	1.34	0.80	0.84	0.74	1.49	0.90	0.92
	1.5	0.57	1.14	0.69	0.71	0.66	1.32	0.82	0.83

[1] cur = 1998 in Cortes (2002a) and 2001 in all present analyses
[2] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[3] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 22. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (baseline scenario)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those reported in the 2002 sensitivity analysis using equal weights and the same form of the model (Cortés 2002a), which included data up to 1997 only. Predictions of alternative harvesting policies from the two forms of the model are also included.

	Cortes (2002a)		**Equal weighting**		**Inverse σ^2 weighting**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	12631	0.44	9630	0.32	9482	0.35
r	0.18	0.81	0.17	0.75	0.18	0.69
C_0	308	0.41	309	0.44	322	0.44
N_{cur}[1]	9746	0.53	6650	0.43	6581	0.46
N_{cur}/K	0.74	0.22	0.68	0.26	0.68	0.26
MSC	493	0.81	378	0.68	381	0.64
F_{cur}/F_{msy}	---	---	0.52	1.09	0.48	0.92

		Equal weighting				**Inverse σ^2 weighting**			
Horizon	**TAC**[2]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[3]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.84	1.68	0.96	1	0.86	1.71	0.98	1
(2011)	0.5	0.78	1.56	0.91	0.97	0.80	1.59	0.94	0.99
	0.8	0.74	1.48	0.87	0.90	0.75	1.51	0.89	0.93
	1.0	0.71	1.42	0.84	0.81	0.72	1.45	0.86	0.86
	1.2	0.68	1.36	0.81	0.67	0.69	1.39	0.83	0.73
	1.5	0.64	1.27	0.75	0.20	0.64	1.29	0.77	0.25
20-year	0	0.92	1.83	0.99	1	0.93	1.86	1	1
(2021)	0.5	0.83	1.65	0.94	0.97	0.85	1.69	0.97	0.99
	0.8	0.76	1.53	0.89	0.90	0.78	1.57	0.92	0.93
	1.0	0.72	1.43	0.84	0.81	0.74	1.48	0.87	0.86
	1.2	0.67	1.34	0.79	0.67	0.69	1.38	0.82	0.72
	1.5	0.60	1.19	0.70	0.17	0.61	1.22	0.72	0.21
30-year	0	0.95	1.90	1	1	0.96	1.93	1	1
(2031)	0.5	0.85	1.70	0.96	0.97	0.87	1.74	0.98	0.99
	0.8	0.77	1.55	0.89	0.90	0.80	1.60	0.93	0.93
	1.0	0.72	1.43	0.84	0.81	0.74	1.48	0.87	0.86
	1.2	0.66	1.31	0.78	0.66	0.68	1.36	0.81	0.72
	1.5	0.57	1.13	0.67	0.16	0.58	1.17	0.70	0.20

[1] $_{cur}$ = 1998 in Cortes (2002a) and 2001 in all present analyses
[2] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[3] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 23. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (alternative catch scenario)** using equal weighting are compared to those for the updated (Table 17) and baseline (Table 18) scenarios using equal weighting. Predictions of alternative harvesting policies for the alternative scenario are also included.

	Alternative catch		Updated catch		Baseline catch	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	10347	0.30	8939	0.39	12229	0.34
r	0.14	0.59	0.16	0.71	0.13	0.73
C_0	515	0.58	369	0.48	418	0.51
N_{2001}	4098	0.51	3413	0.52	4315	0.51
N_{2001}/K	0.39	0.27	0.39	0.29	0.35	0.30
MSC	322	0.34	285	0.32	315	0.36
F_{2001}/F_{msy}	1.49	0.75	1.53	0.71	2.04	0.73

		Alternative catch			
Horizon	**TAC[1]**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.66	1.32	0.78	1
(2011)	0.5	0.53	1.05	0.54	0.83
	0.8	0.43	0.85	0.36	0.55
	1.0	0.35	0.71	0.26	0.37
	1.2	0.28	0.56	0.17	0.19
	1.5	0.18	0.36	0.07	0.01
20-year	0	0.82	1.64	0.94	1
(2021)	0.5	0.61	1.21	0.67	0.83
	0.8	0.43	0.87	0.46	0.55
	1.0	0.31	0.62	0.30	0.37
	1.2	0.20	0.40	0.18	0.18
	1.5	0.08	0.16	0.05	0.01
30-year	0	0.90	1.79	0.98	1
(2031)	0.5	0.65	1.29	0.73	0.84
	0.8	0.43	0.87	0.50	0.55
	1.0	0.29	0.58	0.33	0.37
	1.2	0.17	0.34	0.18	0.18
	1.5	0.06	0.11	0.04	0.01

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 24. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (with fishery-dependent cpue series only)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those of the baseline analysis using equal weights (Table 20). Predictions of alternative harvesting policies from the two forms of the model are also included.

	Baseline catch		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	12229	0.34	12600	0.29	11990	0.21
r	0.13	0.73	0.09	0.75	0.07	0.67
C_0	418	0.51	417	0.50	317	0.43
N_{2001}	4315	0.51	2940	0.65	1312	0.42
N_{2001}/K	0.35	0.30	0.23	0.43	0.11	0.39
MSC	315	0.36	249	0.42	201	0.43
F_{2001}/F_{msy}	2.04	0.73	4.48	0.83	10.6	0.66

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.39	0.78	0.25	1	0.19	0.38	0.03	0.99
(2011)	0.5	0.24	0.48	0.11	0.37	0.03	0.06	0.01	0.03
	0.8	0.15	0.30	0.05	0.13	0.02	0.03	0	0.01
	1.0	0.10	0.21	0.03	0.06	0.01	0.03	0	0
	1.2	0.07	0.14	0.02	0.02	0.01	0.03	0	0
	1.5	0.04	0.09	0.01	0	0.01	0.02	0	0
20-year	0	0.56	1.12	0.56	1	0.32	0.65	0.18	1
(2021)	0.5	0.26	0.51	0.20	0.39	0.02	0.04	0.02	0.03
	0.8	0.12	0.24	0.08	0.13	0.01	0.03	0	0.01
	1.0	0.07	0.14	0.04	0.06	0.01	0.03	0	0
	1.2	0.04	0.08	0.02	0.02	0.01	0.02	0	0
	1.5	0.02	0.04	0.01	0	0.01	0.02	0	0
30-year	0	0.68	1.36	0.72	1	0.46	0.92	0.37	1
(2031)	0.5	0.27	0.55	0.27	0.40	0.02	0.05	0.02	0.03
	0.8	0.11	0.22	0.10	0.13	0.01	0.03	0.01	0.01
	1.0	0.06	0.12	0.05	0.06	0.01	0.02	0	0
	1.2	0.03	0.06	0.02	0.02	0.01	0.02	0	0
	1.5	0.02	0.03	0	0	0.01	0.02	0	0

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 25. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (with fishery-dependent cpue series + the BLL Logs ST series)** using equal weighting are compared to those obtained with fishery-dependent cpue series only using equal weights (Table 24). Predictions of alternative harvesting policies are also included.

	F-D cpue only		**F-D cpue +BLL Logs ST**	
Parameter	**EV**	**CV**	**EV**	**CV**
K	12600	0.29	12544	0.28
r	0.09	0.75	0.09	0.69
C_0	417	0.50	403	0.48
N_{2001}	2940	0.65	3142	0.60
N_{2001}/K	0.23	0.43	0.25	0.41
MSC	249	0.42	254	0.40
F_{2001}/F_{msy}	4.48	0.83	3.92	0.79

		F-D cpue only				**F-D cpue +BLL Logs ST**			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.39	0.78	0.25	1	0.42	0.83	0.29	1
(2011)	0.5	0.24	0.48	0.11	0.37	0.27	0.53	0.13	0.44
	0.8	0.15	0.30	0.05	0.13	0.17	0.34	0.06	0.16
	1.0	0.10	0.21	0.03	0.06	0.12	0.24	0.03	0.07
	1.2	0.07	0.14	0.02	0.02	0.08	0.17	0.02	0.02
	1.5	0.04	0.09	0.01	0	0.05	0.10	0.01	0
20-year	0	0.56	1.12	0.56	1	0.59	1.18	0.61	1
(2021)	0.5	0.26	0.51	0.20	0.39	0.29	0.58	0.24	0.46
	0.8	0.12	0.24	0.08	0.13	0.14	0.28	0.10	0.17
	1.0	0.07	0.14	0.04	0.06	0.08	0.16	0.05	0.07
	1.2	0.04	0.08	0.02	0.02	0.04	0.09	0.02	0.02
	1.5	0.02	0.04	0.01	0	0.02	0.04	0	0
30-year	0	0.68	1.36	0.72	1	0.71	1.42	0.78	1
(2031)	0.5	0.27	0.55	0.27	0.40	0.31	0.63	0.31	0.46
	0.8	0.11	0.22	0.10	0.13	0.13	0.26	0.13	0.17
	1.0	0.06	0.12	0.05	0.06	0.07	0.13	0.06	0.07
	1.2	0.03	0.06	0.02	0.02	0.03	0.07	0.02	0.02
	1.5	0.02	0.03	0	0	0.02	0.03	0	0

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 26. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (with fishery-dependent cpue series only)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those of the baseline analysis using equal weights (Table 21). Predictions of alternative harvesting policies from the two forms of the model are also included.

	Baseline catch		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	2872	0.43	3780	0.33	3055	0.46
r	0.19	0.74	0.13	0.74	0.24	0.60
C_0	113	0.52	124	0.52	124	0.52
N_{2001}	1428	0.52	2013	0.54	2029	0.21
N_{2001}/K	0.50	0.27	0.52	0.37	0.66	0.21
MSC	105	0.31	110	0.60	146	0.37
F_{2001}/F_{msy}	1.16	0.74	1.51	1.16	0.61	0.62

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.71	1.42	0.81	1	0.89	1.79	0.99	1
(2011)	0.5	0.66	1.31	0.74	0.95	0.85	1.70	0.98	1
	0.8	0.62	1.23	0.69	0.85	0.82	1.63	0.97	0.99
	1.0	0.59	1.18	0.65	0.79	0.79	1.59	0.96	0.99
	1.2	0.56	1.13	0.62	0.71	0.77	1.54	0.95	0.97
	1.5	0.52	1.04	0.56	0.57	0.73	1.46	0.93	0.94
20-year	0	0.83	1.65	0.92	1	0.96	1.92	1	1
(2021)	0.5	0.74	1.47	0.83	0.95	0.90	1.81	0.99	1
	0.8	0.67	1.34	0.77	0.86	0.87	1.73	0.99	0.99
	1.0	0.63	1.25	0.71	0.80	0.84	1.67	0.98	0.99
	1.2	0.58	1.16	0.66	0.72	0.81	1.61	0.97	0.98
	1.5	0.51	1.02	0.57	0.58	0.76	1.52	0.94	0.94
30-year	0	0.89	1.78	0.96	1	0.98	1.97	1	1
(2031)	0.5	0.78	1.56	0.87	0.95	0.92	1.85	1	1
	0.8	0.70	1.40	0.80	0.87	0.88	1.77	0.99	0.99
	1.0	0.65	1.29	0.75	0.80	0.85	1.71	0.98	0.99
	1.2	0.59	1.18	0.68	0.72	0.82	1.64	0.97	0.98
	1.5	0.50	1	0.58	0.58	0.77	1.54	0.95	0.94

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 27. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (with fishery-dependent cpue series + the Shark observer and LPS series)** using equal weighting are compared to those obtained with fishery-dependent cpue series only using equal weights (Table 22). Predictions of alternative harvesting policies are also included.

	F-D cpue only		**F-D cpue +Shark Obs+ LPS**	
Parameter	**EV**	**CV**	**EV**	**CV**
K	3780	0.33	3248	0.32
r	0.13	0.74	0.11	0.70
C_0	124	0.52	117	0.53
N_{2001}	2013	0.54	1071	0.62
N_{2001}/K	0.52	0.37	0.32	0.41
MSC	110	0.60	74	0.41
F_{2001}/F_{msy}	1.51	1.16	2.93	0.82

		F-D cpue only				**F-D cpue +Shark Obs+ LPS**			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.71	1.42	0.81	1	0.52	1.05	0.51	1
(2011)	0.5	0.66	1.31	0.74	0.95	0.44	0.89	0.37	0.85
	0.8	0.62	1.23	0.69	0.85	0.39	0.77	0.29	0.64
	1.0	0.59	1.18	0.65	0.79	0.35	0.69	0.24	0.49
	1.2	0.56	1.13	0.62	0.71	0.30	0.61	0.20	0.37
	1.5	0.52	1.04	0.56	0.57	0.25	0.49	0.14	0.21
20-year	0	0.83	1.65	0.92	1	0.69	1.39	0.78	1
(2021)	0.5	0.74	1.47	0.83	0.95	0.55	1.09	0.57	0.86
	0.8	0.67	1.34	0.77	0.86	0.44	0.88	0.43	0.65
	1.0	0.63	1.25	0.71	0.80	0.36	0.73	0.34	0.50
	1.2	0.58	1.16	0.66	0.72	0.29	0.59	0.27	0.38
	1.5	0.51	1.02	0.57	0.58	0.20	0.41	0.18	0.21
30-year	0	0.89	1.78	0.96	1	0.80	1.59	0.89	1
(2031)	0.5	0.78	1.56	0.87	0.95	0.61	1.23	0.67	0.87
	0.8	0.70	1.40	0.80	0.87	0.47	0.94	0.50	0.66
	1.0	0.65	1.29	0.75	0.80	0.38	0.76	0.40	0.51
	1.2	0.59	1.18	0.68	0.72	0.29	0.59	0.31	0.38
	1.5	0.50	1	0.58	0.58	0.19	0.37	0.19	0.21

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 28. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (with fishery-dependent cpue series only)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those of the baseline analysis using equal weights (Table 22). Predictions of alternative harvesting policies from the two forms of the model are also included.

	Baseline catch		**Equal weighting**		**Inverse σ^2 weighting**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	9630	0.32	9583	0.32	7976	0.36
r	0.17	0.75	0.16	0.77	0.13	0.69
C_0	309	0.44	306	0.44	345	0.43
N_{2001}	6650	0.43	6399	0.46	3951	0.49
N_{2001}/K	0.68	0.26	0.65	0.29	0.49	0.31
MSC	378	0.68	355	0.71	218	0.37
F_{2001}/F_{msy}	0.52	1.09	0.62	1.18	0.98	0.74

		Equal weighting				**Inverse σ^2 weighting**			
Horizon	**TAC**[1]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.82	1.63	0.93	1	0.70	1.41	0.86	1
(2011)	0.5	0.75	1.51	0.87	0.95	0.61	1.22	0.72	0.93
	0.8	0.71	1.42	0.83	0.86	0.55	1.09	0.61	0.74
	1.0	0.68	1.36	0.80	0.77	0.50	1	0.54	0.57
	1.2	0.65	1.30	0.76	0.63	0.45	0.90	0.45	0.40
	1.5	0.60	1.21	0.71	0.18	0.38	0.75	0.34	0.17
20-year	0	0.90	1.80	0.98	1	0.83	1.67	0.96	1
(2021)	0.5	0.80	1.60	0.91	0.96	0.69	1.38	0.82	0.93
	0.8	0.73	1.46	0.85	0.86	0.58	1.15	0.67	0.74
	1.0	0.68	1.37	0.80	0.76	0.49	0.99	0.56	0.57
	1.2	0.63	1.27	0.74	0.62	0.41	0.82	0.44	0.39
	1.5	0.56	1.12	0.65	0.15	0.30	0.59	0.28	0.15
30-year	0	0.94	1.88	0.99	1	0.9	1.8	0.99	1
(2031)	0.5	0.83	1.65	0.93	0.96	0.73	1.46	0.86	0.93
	0.8	0.74	1.48	0.85	0.86	0.59	1.18	0.69	0.74
	1.0	0.68	1.36	0.79	0.76	0.49	0.97	0.57	0.57
	1.2	0.62	1.24	0.73	0.62	0.38	0.77	0.43	0.38
	1.5	0.53	1.06	0.61	0.14	0.25	0.50	0.25	0.15

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 29. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (with fishery-dependent cpue series + the Driftnet observer series)** using equal weighting are compared to those obtained with fishery-dependent cpue series only using equal weights (Table 28). Predictions of alternative harvesting policies are also included.

	F-D cpue only		**F-D cpue +Driftnet observer**	
Parameter	**EV**	**CV**	**EV**	**CV**
K	9583	0.32	9416	0.32
r	0.16	0.77	0.15	0.79
C_0	306	0.44	303	0.43
N_{2001}	6399	0.46	5892	0.51
N_{2001}/K	0.65	0.29	0.60	0.34
MSC	355	0.71	315	0.75
F_{2001}/F_{msy}	0.62	1.18	0.80	1.15

		F-D cpue only				**F-D cpue +Driftnet observer**			
Horizon	**TAC[1]**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.82	1.63	0.93	1	0.77	1.55	0.88	1
(2011)	0.5	0.75	1.51	0.87	0.95	0.70	1.40	0.81	0.93
	0.8	0.71	1.42	0.83	0.86	0.65	1.30	0.75	0.79
	1.0	0.68	1.36	0.80	0.77	0.62	1.23	0.70	0.68
	1.2	0.65	1.30	0.76	0.63	0.58	1.16	0.66	0.53
	1.5	0.60	1.21	0.71	0.18	0.53	1.06	0.59	0.14
20-year	0	0.90	1.80	0.98	1	0.87	1.74	0.96	1
(2021)	0.5	0.80	1.60	0.91	0.96	0.75	1.51	0.86	0.93
	0.8	0.73	1.46	0.85	0.86	0.67	1.34	0.77	0.79
	1.0	0.68	1.37	0.80	0.76	0.61	1.23	0.70	0.68
	1.2	0.63	1.27	0.74	0.62	0.56	1.11	0.64	0.53
	1.5	0.56	1.12	0.65	0.15	0.48	0.95	0.53	0.11
30-year	0	0.94	1.88	0.99	1	0.92	1.84	0.99	1
(2031)	0.5	0.83	1.65	0.93	0.96	0.78	1.56	0.88	0.93
	0.8	0.74	1.48	0.85	0.86	0.68	1.36	0.78	0.79
	1.0	0.68	1.36	0.79	0.76	0.61	1.21	0.70	0.68
	1.2	0.62	1.24	0.73	0.62	0.54	1.07	0.63	0.53
	1.5	0.53	1.06	0.61	0.14	0.44	0.88	0.50	0.11

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch

[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 30. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (with fishery-independent cpue series only)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those of the baseline analysis using equal weights (Table 20). Predictions of alternative harvesting policies from the two forms of the model are also included.

	Baseline catch		**Equal weighting**		**Inverse σ^2 weighting**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	12229	0.34	16742	0.45	8169	0.66
r	0.13	0.73	0.15	0.81	0.38	0.89
C_0	418	0.51	511	0.53	310	0.43
N_{2001}	4315	0.51	10156	0.62	3716	1.01
N_{2001}/K	0.35	0.30	0.59	0.27	0.52	0.49
MSC	315	0.36	479	0.53	437	0.53
F_{2001}/F_{msy}	2.04	0.73	0.89	0.88	3.75	1.40

		Equal weighting				**Inverse σ^2 weighting**			
Horizon	**TAC[1]**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.78	1.57	0.92	1	0.73	1.46	0.72	1
(2011)	0.5	0.71	1.41	0.85	0.94	0.63	1.25	0.71	0.72
	0.8	0.65	1.30	0.78	0.80	0.59	1.18	0.71	0.71
	1.0	0.61	1.23	0.73	0.68	0.56	1.12	0.70	0.69
	1.2	0.57	1.15	0.66	0.50	0.52	1.05	0.69	0.61
	1.5	0.51	1.02	0.56	0.08	0.46	0.93	0.65	0.20
20-year	0	0.88	1.76	0.97	1	0.77	1.54	0.72	1
(2021)	0.5	0.76	1.53	0.89	0.94	0.64	1.29	0.71	0.72
	0.8	0.68	1.36	0.81	0.80	0.60	1.21	0.71	0.71
	1.0	0.62	1.23	0.73	0.68	0.57	1.14	0.70	0.69
	1.2	0.55	1.10	0.64	0.50	0.53	1.06	0.68	0.61
	1.5	0.44	0.88	0.50	0.07	0.45	0.90	0.63	0.18
30-year	0	0.93	1.85	0.99	1	0.79	1.59	0.72	1
(2031)	0.5	0.79	1.58	0.91	0.94	0.65	1.30	0.72	0.72
	0.8	0.69	1.38	0.82	0.80	0.61	1.21	0.71	0.71
	1.0	0.61	1.22	0.73	0.68	0.57	1.14	0.70	0.69
	1.2	0.53	1.05	0.62	0.50	0.53	1.06	0.68	0.61
	1.5	0.39	0.78	0.46	0.06	0.44	0.88	0.62	0.17

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 31. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (with fishery-independent cpue series only)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those of the baseline analysis using equal weights (Table 21). Predictions of alternative harvesting policies from the two forms of the model are also included.

	Baseline catch		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	2872	0.43	3347	0.38	3706	0.29
r	0.19	0.74	0.16	0.77	0.09	0.72
C_0	113	0.52	123	0.53	106	0.48
N_{2001}	1428	0.52	1722	0.51	1467	0.54
N_{2001}/K	0.50	0.27	0.52	0.30	0.39	0.40
MSC	105	0.31	104	0.39	72	0.47
F_{2001}/F_{msy}	1.16	0.74	1.24	0.84	2.71	0.93

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[1]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.75	1.49	0.89	1	0.55	1.09	0.56	1
(2011)	0.5	0.69	1.38	0.82	0.98	0.48	0.96	0.44	0.85
	0.8	0.65	1.30	0.76	0.92	0.43	0.86	0.37	0.64
	1.0	0.62	1.24	0.72	0.86	0.40	0.80	0.32	0.50
	1.2	0.59	1.18	0.68	0.78	0.37	0.74	0.29	0.39
	1.5	0.54	1.09	0.60	0.64	0.32	0.64	0.23	0.24
20-year	0	0.86	1.73	0.96	1	0.69	1.37	0.79	1
(2021)	0.5	0.78	1.55	0.90	0.98	0.56	1.11	0.59	0.87
	0.8	0.72	1.43	0.84	0.93	0.47	0.93	0.47	0.66
	1.0	0.67	1.34	0.79	0.87	0.41	0.81	0.39	0.51
	1.2	0.62	1.25	0.73	0.78	0.35	0.70	0.32	0.39
	1.5	0.55	1.09	0.62	0.64	0.27	0.54	0.23	0.24
30-year	0	0.92	1.84	0.99	1	0.78	1.56	0.89	1
(2031)	0.5	0.82	1.64	0.93	0.98	0.61	1.22	0.67	0.88
	0.8	0.75	1.50	0.87	0.93	0.49	0.98	0.52	0.66
	1.0	0.70	1.39	0.82	0.87	0.41	0.82	0.43	0.51
	1.2	0.64	1.27	0.75	0.79	0.34	0.67	0.35	0.40
	1.5	0.54	1.08	0.63	0.65	0.24	0.49	0.24	0.24

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 32. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (with fishery-independent cpue series only)** using two separate weighting methods (equal weighting and inverse variance weighting) are compared to those of the baseline analysis using equal weights (Table 22). Predictions of alternative harvesting policies from the two forms of the model are also included.

	Baseline catch		Equal weighting		Inverse σ^2 weighting	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K	9630	0.32	9187	0.34	9146	0.36
r	0.17	0.75	0.18	0.79	0.21	0.74
C_0	309	0.44	302	0.44	310	0.45
N_{2001}	6650	0.43	6230	0.48	6577	0.45
N_{2001}/K	0.68	0.26	0.66	0.30	0.71	0.24
MSC	378	0.68	378	0.74	420	0.68
F_{2001}/F_{msy}	0.52	1.09	0.64	1.58	0.44	1.31

		Equal weighting				Inverse σ^2 weighting			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.83	1.66	0.93	1	0.88	1.75	0.97	1
(2011)	0.5	0.77	1.53	0.88	0.95	0.82	1.64	0.95	0.99
	0.8	0.72	1.44	0.83	0.87	0.78	1.56	0.92	0.94
	1.0	0.69	1.39	0.80	0.79	0.75	1.51	0.90	0.88
	1.2	0.66	1.32	0.77	0.64	0.73	1.45	0.88	0.74
	1.5	0.62	1.23	0.73	0.18	0.68	1.37	0.82	0.23
20-year	0	0.91	1.81	0.97	1	0.94	1.88	0.99	1
(2021)	0.5	0.81	1.62	0.91	0.95	0.86	1.72	0.96	0.99
	0.8	0.74	1.49	0.85	0.87	0.81	1.61	0.93	0.94
	1.0	0.70	1.39	0.80	0.79	0.77	1.53	0.90	0.87
	1.2	0.65	1.3	0.76	0.64	0.72	1.45	0.86	0.73
	1.5	0.58	1.16	0.68	0.15	0.65	1.31	0.78	0.20
30-year	0	0.94	1.89	0.99	1	0.97	1.93	1	1
(2031)	0.5	0.83	1.66	0.93	0.95	0.88	1.76	0.97	0.99
	0.8	0.75	1.50	0.86	0.87	0.82	1.63	0.93	0.94
	1.0	0.69	1.39	0.81	0.78	0.77	1.54	0.90	0.87
	1.2	0.64	1.27	0.75	0.63	0.72	1.43	0.85	0.73
	1.5	0.55	1.10	0.66	0.14	0.63	1.26	0.76	0.19

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 33. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (with fishery-independent cpue series + the SC LL series)** using equal weighting are compared to those obtained with fishery-independent cpue series only using equal weights (Table 32). Predictions of alternative harvesting policies are also included.

	F-I cpue only		F-I cpue + SC LL	
Parameter	**EV**	**CV**	**EV**	**CV**
K	9187	0.34	9167	0.35
r	0.18	0.79	0.17	0.80
C_0	302	0.44	303	0.44
N_{2001}	6230	0.48	5988	0.51
N_{2001}/K	0.66	0.30	0.63	0.33
MSC	378	0.74	351	0.74
F_{2001}/F_{msy}	0.64	1.58	0.80	1.79

		F-D cpue only				F-I cpue + SC LL			
Horizon	**TAC[1]**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.83	1.66	0.93	1	0.80	1.60	0.90	1
(2011)	0.5	0.77	1.53	0.88	0.95	0.73	1.46	0.83	0.93
	0.8	0.72	1.44	0.83	0.87	0.68	1.36	0.78	0.82
	1.0	0.69	1.39	0.80	0.79	0.65	1.30	0.75	0.73
	1.2	0.66	1.32	0.77	0.64	0.62	1.23	0.71	0.59
	1.5	0.62	1.23	0.73	0.18	0.57	1.14	0.66	0.16
20-year	0	0.91	1.81	0.97	1	0.88	1.77	0.96	1
(2021)	0.5	0.81	1.62	0.91	0.95	0.78	1.55	0.88	0.93
	0.8	0.74	1.49	0.85	0.87	0.70	1.40	0.80	0.82
	1.0	0.70	1.39	0.80	0.79	0.65	1.30	0.75	0.73
	1.2	0.65	1.3	0.76	0.64	0.60	1.20	0.69	0.58
	1.5	0.58	1.16	0.68	0.15	0.52	1.05	0.61	0.14
30-year	0	0.94	1.89	0.99	1	0.93	1.86	0.98	1
(2031)	0.5	0.83	1.66	0.93	0.95	0.80	1.60	0.89	0.93
	0.8	0.75	1.50	0.86	0.87	0.71	1.42	0.81	0.83
	1.0	0.69	1.39	0.81	0.78	0.64	1.29	0.75	0.73
	1.2	0.64	1.27	0.75	0.63	0.58	1.17	0.68	0.58
	1.5	0.55	1.10	0.66	0.14	0.50	0.99	0.58	0.13

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch

[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 34. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (adding the BLL Logs ST cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 20). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		21 cpue series	
Parameter	**EV**	**CV**	**EV**	**CV**
K	12229	0.34	12126	0.35
r	0.13	0.73	0.13	0.73
C_0	418	0.51	420	0.51
N_{2001}	4315	0.51	4383	0.52
N_{2001}/K	0.35	0.30	0.36	0.29
MSC	315	0.36	322	0.35
F_{2001}/F_{msy}	2.04	0.73	1.92	0.72

		Baseline				21 cpue series			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.59	1.19	0.65	1	0.61	1.21	0.68	1
(2011)	0.5	0.47	0.94	0.41	0.78	0.48	0.97	0.45	0.79
	0.8	0.38	0.75	0.27	0.48	0.39	0.78	0.30	0.51
	1.0	0.31	0.62	0.18	0.29	0.33	0.65	0.21	0.32
	1.2	0.24	0.49	0.12	0.15	0.26	0.52	0.13	0.17
	1.5	0.16	0.31	0.05	0.02	0.16	0.33	0.05	0.02
20-year	0	0.76	1.51	0.87	1	0.77	1.53	0.88	1
(2021)	0.5	0.55	1.09	0.58	0.79	0.56	1.13	0.61	0.8
	0.8	0.38	0.75	0.36	0.48	0.40	0.80	0.4	0.52
	1.0	0.26	0.53	0.24	0.29	0.29	0.57	0.26	0.32
	1.2	0.17	0.34	0.13	0.15	0.18	0.37	0.15	0.17
	1.5	0.07	0.14	0.04	0.02	0.08	0.15	0.04	0.02
30-year	0	0.85	1.69	0.94	1	0.85	1.71	0.94	1
(2031)	0.5	0.59	1.18	0.65	0.80	0.61	1.21	0.68	0.81
	0.8	0.37	0.75	0.41	0.48	0.40	0.80	0.44	0.52
	1.0	0.24	0.49	0.26	0.29	0.27	0.53	0.29	0.32
	1.2	0.14	0.28	0.14	0.15	0.15	0.31	0.16	0.17
	1.5	0.05	0.10	0.03	0.02	0.05	0.10	0.04	0.02

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 35. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (adding the Shark observer cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 21). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		11 cpue series	
Parameter	EV	CV	EV	CV
K	2872	0.43	2777	0.44
r	0.19	0.74	0.21	0.71
C_0	113	0.52	112	0.52
N_{2001}	1428	0.52	1414	0.53
N_{2001}/K	0.50	0.27	0.52	0.26
MSC	105	0.31	109	0.29
F_{2001}/F_{msy}	1.16	0.74	1.07	0.70

		Baseline				11 cpue series			
Horizon	TAC[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.78	1.55	0.92	1	0.80	1.60	0.93	1
(2011)	0.5	0.72	1.43	0.85	0.99	0.74	1.48	0.88	0.99
	0.8	0.67	1.35	0.80	0.95	0.70	1.39	0.84	0.96
	1.0	0.64	1.29	0.76	0.90	0.66	1.33	0.80	0.92
	1.2	0.61	1.22	0.72	0.83	0.63	1.26	0.76	0.86
	1.5	0.56	1.12	0.64	0.71	0.58	1.16	0.68	0.75
20-year	0	0.89	1.78	0.98	1	0.91	1.81	0.98	1
(2021)	0.5	0.81	1.62	0.94	0.99	0.83	1.65	0.95	0.99
	0.8	0.75	1.49	0.88	0.95	0.77	1.54	0.90	0.97
	1.0	0.70	1.4	0.83	0.91	0.73	1.45	0.86	0.93
	1.2	0.65	1.31	0.77	0.84	0.68	1.36	0.81	0.87
	1.5	0.57	1.14	0.68	0.71	0.60	1.20	0.72	0.75
30-year	0	0.94	1.88	0.99	1	0.95	1.90	0.99	1
(2031)	0.5	0.85	1.70	0.96	0.99	0.86	1.73	0.97	0.99
	0.8	0.78	1.56	0.91	0.96	0.80	1.60	0.93	0.97
	1.0	0.73	1.46	0.86	0.91	0.75	1.50	0.88	0.93
	1.2	0.67	1.34	0.80	0.84	0.70	1.39	0.84	0.87
	1.5	0.57	1.14	0.69	0.71	0.60	1.20	0.74	0.75

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 36. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (adding the LPS cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 21). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		11 cpue series (+LPS)	
Parameter	**EV**	**CV**	**EV**	**CV**
K	2872	0.43	2768	0.37
r	0.19	0.74	0.16	0.68
C_0	113	0.52	108	0.51
N_{2001}	1428	0.52	1021	0.50
N_{2001}/K	0.50	0.27	0.37	0.29
MSC	105	0.31	88	0.31
F_{2001}/F_{msy}	1.16	0.74	1.87	0.70

		Baseline				11 cpue series (+LPS)			
Horizon	**TAC**[1]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.78	1.55	0.92	1	0.66	1.32	0.76	1
(2011)	0.5	0.72	1.43	0.85	0.99	0.59	1.17	0.64	0.95
	0.8	0.67	1.35	0.80	0.95	0.53	1.06	0.55	0.85
	1.0	0.64	1.29	0.76	0.90	0.49	0.98	0.48	0.75
	1.2	0.61	1.22	0.72	0.83	0.45	0.89	0.40	0.65
	1.5	0.56	1.12	0.64	0.71	0.38	0.76	0.30	0.46
20-year	0	0.89	1.78	0.98	1	0.82	1.64	0.92	1
(2021)	0.5	0.81	1.62	0.94	0.99	0.71	1.41	0.80	0.96
	0.8	0.75	1.49	0.88	0.95	0.62	1.24	0.69	0.86
	1.0	0.70	1.4	0.83	0.91	0.55	1.11	0.61	0.76
	1.2	0.65	1.31	0.77	0.84	0.48	0.96	0.52	0.65
	1.5	0.57	1.14	0.68	0.71	0.37	0.73	0.37	0.46
30-year	0	0.94	1.88	0.99	1	0.90	1.79	0.97	1
(2031)	0.5	0.85	1.70	0.96	0.99	0.77	1.53	0.87	0.96
	0.8	0.78	1.56	0.91	0.96	0.66	1.33	0.76	0.86
	1.0	0.73	1.46	0.86	0.91	0.58	1.17	0.67	0.76
	1.2	0.67	1.34	0.80	0.84	0.50	0.99	0.58	0.65
	1.5	0.57	1.14	0.69	0.71	0.36	0.72	0.41	0.47

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 37. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **sandbar shark (adding the Shark observer and LPS cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 21). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		12 cpue series	
Parameter	**EV**	**CV**	**EV**	**CV**
K	2872	0.43	2676	0.39
r	0.19	0.74	0.18	0.66
C_0	113	0.52	107	0.51
N_{2001}	1428	0.52	1027	0.50
N_{2001}/K	0.50	0.27	0.39	0.28
MSC	105	0.31	92	0.29
F_{2001}/F_{msy}	1.16	0.74	1.68	0.67

		Baseline				12 cpue series			
Horizon	**TAC**[1]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.78	1.55	0.92	1	0.69	1.39	0.81	1
(2011)	0.5	0.72	1.43	0.85	0.99	0.62	1.24	0.70	0.97
	0.8	0.67	1.35	0.80	0.95	0.56	1.13	0.61	0.89
	1.0	0.64	1.29	0.76	0.90	0.52	1.05	0.54	0.80
	1.2	0.61	1.22	0.72	0.83	0.48	0.96	0.47	0.70
	1.5	0.56	1.12	0.64	0.71	0.41	0.83	0.36	0.51
20-year	0	0.89	1.78	0.98	1	0.85	1.69	0.95	1
(2021)	0.5	0.81	1.62	0.94	0.99	0.74	1.48	0.85	0.98
	0.8	0.75	1.49	0.88	0.95	0.66	1.31	0.75	0.90
	1.0	0.70	1.4	0.83	0.91	0.59	1.19	0.67	0.81
	1.2	0.65	1.31	0.77	0.84	0.52	1.05	0.58	0.70
	1.5	0.57	1.14	0.68	0.71	0.41	0.82	0.44	0.52
30-year	0	0.94	1.88	0.99	1	0.91	1.83	0.98	1
(2031)	0.5	0.85	1.70	0.96	0.99	0.80	1.59	0.90	0.98
	0.8	0.78	1.56	0.91	0.96	0.70	1.40	0.81	0.90
	1.0	0.73	1.46	0.86	0.91	0.63	1.25	0.72	0.81
	1.2	0.67	1.34	0.80	0.84	0.54	1.08	0.63	0.71
	1.5	0.57	1.14	0.69	0.71	0.40	0.81	0.47	0.52

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 38. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (adding the Driftnet observer cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 22). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		**9 cpue series**	
Parameter	**EV**	**CV**	**EV**	**CV**
K	9630	0.32	9556	0.32
r	0.17	0.75	0.16	0.77
C_0	309	0.44	305	0.43
N_{2001}	6650	0.43	6275	0.47
N_{2001}/K	0.68	0.26	0.64	0.30
MSC	378	0.68	342	0.72
F_{2001}/F_{msy}	0.52	1.09	0.64	1.09

		Baseline				**9 cpue series**			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.84	1.68	0.96	1	0.81	1.62	0.93	1
(2011)	0.5	0.78	1.56	0.91	0.97	0.74	1.49	0.87	0.96
	0.8	0.74	1.48	0.87	0.90	0.70	1.40	0.81	0.86
	1.0	0.71	1.42	0.84	0.81	0.67	1.33	0.78	0.75
	1.2	0.68	1.36	0.81	0.67	0.64	1.27	0.73	0.61
	1.5	0.64	1.27	0.75	0.20	0.59	1.17	0.67	0.18
20-year	0	0.92	1.83	0.99	1	0.90	1.79	0.98	1
(2021)	0.5	0.83	1.65	0.94	0.97	0.79	1.59	0.91	0.96
	0.8	0.76	1.53	0.89	0.90	0.72	1.44	0.84	0.86
	1.0	0.72	1.43	0.84	0.81	0.67	1.34	0.78	0.75
	1.2	0.67	1.34	0.79	0.67	0.62	1.23	0.72	0.60
	1.5	0.60	1.19	0.70	0.17	0.54	1.08	0.62	0.14
30-year	0	0.95	1.90	1	1	0.94	1.88	0.99	1
(2031)	0.5	0.85	1.70	0.96	0.97	0.82	1.64	0.93	0.96
	0.8	0.77	1.55	0.89	0.90	0.73	1.46	0.85	0.86
	1.0	0.72	1.43	0.84	0.81	0.67	1.33	0.78	0.75
	1.2	0.66	1.31	0.78	0.66	0.60	1.20	0.70	0.60
	1.5	0.57	1.13	0.67	0.16	0.51	1.01	0.59	0.14

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 39. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (adding the SC LL cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 22). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		**9 cpue series (+SC LL)**	
Parameter	**EV**	**CV**	**EV**	**CV**
K	9630	0.32	9721	0.31
r	0.17	0.75	0.17	0.82
C_0	309	0.44	304	0.43
N_{2001}	6650	0.43	6576	0.45
N_{2001}/K	0.68	0.26	0.66	0.29
MSC	378	0.68	381	0.80
F_{2001}/F_{msy}	0.52	1.09	0.62	1.22

		Baseline				**9 cpue series (+SC LL)**			
Horizon	**TAC[1]**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K[2]**	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.84	1.68	0.96	1	0.82	1.64	0.93	1
(2011)	0.5	0.78	1.56	0.91	0.97	0.76	1.51	0.87	0.95
	0.8	0.74	1.48	0.87	0.90	0.71	1.43	0.82	0.86
	1.0	0.71	1.42	0.84	0.81	0.69	1.37	0.79	0.76
	1.2	0.68	1.36	0.81	0.67	0.66	1.31	0.76	0.61
	1.5	0.64	1.27	0.75	0.20	0.61	1.22	0.70	0.16
20-year	0	0.92	1.83	0.99	1	0.90	1.79	0.98	1
(2021)	0.5	0.83	1.65	0.94	0.97	0.80	1.60	0.91	0.96
	0.8	0.76	1.53	0.89	0.90	0.73	1.47	0.84	0.86
	1.0	0.72	1.43	0.84	0.81	0.69	1.37	0.79	0.76
	1.2	0.67	1.34	0.79	0.67	0.64	1.28	0.74	0.61
	1.5	0.60	1.19	0.70	0.17	0.57	1.14	0.66	0.13
30-year	0	0.95	1.90	1	1	0.94	1.88	0.99	1
(2031)	0.5	0.85	1.70	0.96	0.97	0.82	1.65	0.92	0.96
	0.8	0.77	1.55	0.89	0.90	0.74	1.48	0.85	0.86
	1.0	0.72	1.43	0.84	0.81	0.68	1.37	0.79	0.76
	1.2	0.66	1.31	0.78	0.66	0.62	1.25	0.73	0.60
	1.5	0.57	1.13	0.67	0.16	0.54	1.07	0.62	0.13

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 40. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **blacktip shark (adding the Driftnet observer and SC LL cpue series to the baseline scenario)** using equal weights are compared to those of the baseline analysis using equal weights (Table 22). Predictions of alternative harvesting policies from the two models are also included.

	Baseline		10 cpue series	
Parameter	**EV**	**CV**	**EV**	**CV**
K	9630	0.32	9522	0.32
r	0.17	0.75	0.14	0.81
C_0	309	0.44	302	0.43
N_{2001}	6650	0.43	5922	0.51
N_{2001}/K	0.68	0.26	0.60	0.34
MSC	378	0.68	312	0.77
F_{2001}/F_{msy}	0.52	1.09	0.82	1.11

		Baseline				10 cpue series			
Horizon	**TAC**[1]	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**	**N_{fin}/K**[2]	**N_{fin}/N_{msy}**	**$P(N_{fin}>N_{msy})$**	**$P(N_{fin}>N_{2001})$**
10-year	0	0.84	1.68	0.96	1	0.77	1.54	0.89	1
(2011)	0.5	0.78	1.56	0.91	0.97	0.70	1.40	0.80	0.94
	0.8	0.74	1.48	0.87	0.90	0.65	1.30	0.74	0.79
	1.0	0.71	1.42	0.84	0.81	0.61	1.23	0.69	0.67
	1.2	0.68	1.36	0.81	0.67	0.58	1.16	0.65	0.52
	1.5	0.64	1.27	0.75	0.20	0.53	1.06	0.58	0.13
20-year	0	0.92	1.83	0.99	1	0.87	1.73	0.96	1
(2021)	0.5	0.83	1.65	0.94	0.97	0.75	1.50	0.85	0.94
	0.8	0.76	1.53	0.89	0.90	0.67	1.33	0.76	0.79
	1.0	0.72	1.43	0.84	0.81	0.61	1.22	0.69	0.67
	1.2	0.67	1.34	0.79	0.67	0.55	1.1	0.63	0.51
	1.5	0.60	1.19	0.70	0.17	0.47	0.95	0.53	0.11
30-year	0	0.95	1.90	1	1	0.92	1.84	0.99	1
(2031)	0.5	0.85	1.70	0.96	0.97	0.78	1.56	0.88	0.94
	0.8	0.77	1.55	0.89	0.90	0.67	1.35	0.77	0.79
	1.0	0.72	1.43	0.84	0.81	0.60	1.20	0.69	0.67
	1.2	0.66	1.31	0.78	0.66	0.53	1.06	0.61	0.51
	1.5	0.57	1.13	0.67	0.16	0.44	0.87	0.50	0.1

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 41. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the **Bayesian surplus production model analysis using the SIR algorithm**. Results for the **large coastal shark complex (alternative catch scenario with modifications in menhaden discards)** using equal weighting are compared to those for the alternative catch scenario (Table 23) using equal weighting. Predictions of alternative harvesting policies are also included.

	Alternative catch		**Alternative catch (menhaden discards modified)**	
Parameter	**EV**	**CV**	**EV**	**CV**
K	10347	0.30	10609	0.30
r	0.14	0.59	0.14	0.59
C_0	515	0.58	515	0.58
N_{2001}	4098	0.51	4102	0.50
N_{2001}/K	0.39	0.27	0.38	0.27
MSC	322	0.34	324	0.34
F_{2001}/F_{msy}	1.49	0.75	1.49	0.75

		Alternative catch				**Alternative catch (menhaden discards modified)**			
Horizon	**TAC**[1]	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$	N_{fin}/K[2]	N_{fin}/N_{msy}	$P(N_{fin}>N_{msy})$	$P(N_{fin}>N_{2001})$
10-year	0	0.66	1.32	0.78	1	0.66	1.31	0.78	1
(2011)	0.5	0.53	1.05	0.54	0.83	0.52	1.04	0.53	0.84
	0.8	0.43	0.85	0.36	0.55	0.42	0.84	0.35	0.57
	1.0	0.35	0.71	0.26	0.37	0.35	0.70	0.25	0.37
	1.2	0.28	0.56	0.17	0.19	0.28	0.55	0.16	0.19
	1.5	0.18	0.36	0.07	0.01	0.18	0.35	0.07	0.02
20-year	0	0.82	1.64	0.94	1	0.82	1.64	0.94	1
(2021)	0.5	0.61	1.21	0.67	0.83	0.61	1.21	0.68	0.85
	0.8	0.43	0.87	0.46	0.55	0.43	0.86	0.45	0.57
	1.0	0.31	0.62	0.30	0.37	0.31	0.62	0.30	0.36
	1.2	0.20	0.40	0.18	0.18	0.20	0.39	0.17	0.18
	1.5	0.08	0.16	0.05	0.01	0.08	0.16	0.05	0.01
30-year	0	0.90	1.79	0.98	1	0.9	1.79	0.98	1
(2031)	0.5	0.65	1.29	0.73	0.84	0.65	1.30	0.74	0.85
	0.8	0.43	0.87	0.50	0.55	0.43	0.87	0.50	0.57
	1.0	0.29	0.58	0.33	0.37	0.29	0.58	0.32	0.36
	1.2	0.17	0.34	0.18	0.18	0.17	0.33	0.18	0.18
	1.5	0.06	0.11	0.04	0.01	0.05	0.11	0.04	0.01

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch
[2] N_{fin}/K is the stock abundance in the final year of management (2011, 2021, or 2031) as a percentage of K

Table 42. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian state-space surplus production model (SSSPM) and the Bayesian state-space lagged recruitment, survival, and growth (SSLRSG) model analyses using the MCMC algorithm (implemented in WinBUGS). Results for the **large coastal shark complex (updated scenario)** are compared to those obtained with the Bayesian SPM using the SIR algorithm and equal weighting (Table 17).

	SPM (SIR, equal weighting)		WinBUGS[1] (SSSPM, MCMC)		WinBUGS[2] (SSSPM, MCMC)		WinBUGS[1] (SSLRSG, MCMC)		WinBUGS[2] (SSLRSG, MCMC)	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K (N_0)	8939	0.39	11900	0.97	11380	0.87	5474	0.73	4541	0.26
r	0.16	0.71	0.21	0.69	0.21	0.77	---	---	---	---
C_0	369	0.48	348	0.49	371	0.51	368	0.49	293	0.35
N_{2001}	3413	0.52	6072	1.23	4811	1.07	2258	1.30	1376	0.37
N_{2001}/K	0.39	0.29	0.49	0.25	0.43	0.26	0.38	0.26	0.30	0.23
MSC	285	0.32	403	0.47	379	0.41	348	0.46	294	0.26
z	---	---	---	---	---	---	0.66	0.22	0.63	0.25
s	---	---	---	---	---	---	0.85	0.06	0.84	0.07

[1] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for each series
[2] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for all series.

Table 43. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian state-space surplus production model (SSSPM) and the Bayesian state-space lagged recruitment, survival, and growth (SSLRSG) model analyses using the MCMC algorithm (implemented in WinBUGS). Results for the **sandbar shark (updated scenario)** are compared to those obtained with the Bayesian SPM using the SIR algorithm and equal weighting (Table 18).

	SPM (SIR, equal weighting)		WinBUGS[1] (SSSPM, MCMC)		WinBUGS[2] (SSSPM, MCMC)		WinBUGS[1] (SSLRSG, MCMC)		WinBUGS[2] (SSLRSG, MCMC)	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K (N_0)	3019	0.55	22940	1.04	18670	1.18	3821	2.17	1842	1.92
r	0.23	0.98	0.13	0.94	0.12	0.63	---	---	---	---
C_0	167	0.64	164	0.61	182	0.62	105	0.54	107	0.50
N_{2001}	1402	0.59	16920	1.23	13850	1.38	2588	2.50	1020	2.33
N_{2001}/K	0.50	0.33	0.71	0.40	0.68	0.38	0.52	0.41	0.50	0.30
MSC	110	0.36	592	1.25	459	1.34	142	1.51	113	0.72
z	---	---	---	---	---	---	0.67	0.27	0.69	0.24
s	---	---	---	---	---	---	0.81	0.10	0.80	0.09

[1] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for each series
[2] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for all series.

Table 44. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian state-space surplus production model (SSSPM) and the Bayesian state-space lagged recruitment, survival, and growth (SSLRSG) model analyses using the MCMC algorithm (implemented in WinBUGS). Results for the **blacktip shark (updated scenario)** are compared to those obtained with the Bayesian SPM using the SIR algorithm and equal weighting (Table 19).

	SPM (SIR, equal weighting)		WinBUGS[1] (SSSPM, MCMC)		WinBUGS[2] (SSSPM, MCMC)		WinBUGS[1] (SSLRSG, MCMC)		WinBUGS[2] (SSLRSG, MCMC)	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K (N_0)	10834	0.38	6941	1.29	1472	0.61	5059	1.15	3426	0.61
r	0.18	0.81	0.36	0.63	1.02	0.46	---	---	---	---
C_0	298	0.41	301	0.36	247	0.25	346	0.36	307	0.31
N_{2001}	8034	0.47	5587	1.63	171	0.80	3011	1.99	244	4.42
N_{2001}/K	0.73	0.24	0.71	0.30	0.14	0.87	0.46	0.52	0.03	3.12
MSC	426	0.78	428	1.14	287	0.13	340	1.10	184	0.28
z	---	---	---	---	---	---	0.66	0.25	0.72	0.17
s	---	---	---	---	---	---	0.83	0.06	0.88	0.05

[1] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for each series
[2] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for all series.

Table 45. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian state-space surplus production model (SSSPM) and the Bayesian state-space lagged recruitment, survival, and growth (SSLRSG) model analyses using the MCMC algorithm (implemented in WinBUGS). Results for the **large coastal shark complex (baseline scenario)** are compared to those obtained with the Bayesian SPM using the SIR algorithm and equal weighting (Table 20).

	SPM (SIR, equal weighting)		**WinBUGS[1] (SSSPM, MCMC)**		**WinBUGS[2] (SSSPM, MCMC)**		**WinBUGS[1] (SSLRSG, MCMC)**		**WinBUGS[2] (SSLRSG, MCMC)**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K (N_0)	12229	0.34	15700	0.81	15040	0.64	6684	0.79	5998	0.40
r	0.13	0.73	0.18	0.72	0.14	0.68	---	---	---	---
C_0	418	0.51	380	0.49	417	0.49	305	0.38	332	0.38
N_{2001}	4315	0.51	7930	1.05	5695	0.84	2662	1.46	1713	0.64
N_{2001}/K	0.35	0.30	0.49	0.26	0.37	0.27	0.36	0.27	0.27	0.29
MSC	315	0.36	481	0.44	402	0.40	429	0.51	310	0.35
z	---	---	---	---	---	---	0.65	0.23	0.54	0.31
s	---	---	---	---	---	---	0.84	0.07	0.82	0.10

[1] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for each series
[2] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for all series.

Table 46. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian state-space surplus production model (SSSPM) and the Bayesian state-space lagged recruitment, survival, and growth (SSLRSG) model analyses using the MCMC algorithm (implemented in WinBUGS). Results for the **sandbar shark (baseline scenario)** are compared to those obtained with the Bayesian SPM using the SIR algorithm and equal weighting (Table 21).

	SPM (SIR, equal weighting)		WinBUGS[1] (SSSPM, MCMC)		WinBUGS[2] (SSSPM, MCMC)		WinBUGS[1] (SSLRSG, MCMC)		WinBUGS[2] (SSLRSG, MCMC)	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K (N_0)	2872	0.43	22640	1.04	19600	1.13	2383	2.09	2780	2.12
r	0.19	0.74	0.12	0.60	0.12	0.73	---	---	---	---
C_0	113	0.52	160	0.58	182	0.64	103	0.49	118	0.53
N_{2001}	1428	0.52	16590	1.22	14410	1.34	1435	2.45	1631	2.48
N_{2001}/K	0.50	0.27	0.71	0.38	0.68	0.39	0.49	0.36	0.50	0.35
MSC	105	0.31	576	1.23	480	1.29	122	0.96	129	0.98
z	---	---	---	---	---	---	0.67	0.27	0.68	0.25
s	---	---	---	---	---	---	0.80	0.10	0.81	0.10

[1] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for each series

[2] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for all series.

Table 47. Estimated expected values (EV) of the means and coefficients of variation (CV) of marginal posterior distributions for output parameters from the Bayesian state-space surplus production model (SSSPM) and the Bayesian state-space lagged recruitment, survival, and growth (SSLRSG) model analyses using the MCMC algorithm (implemented in WinBUGS). Results for the **blacktip shark (baseline scenario)** are compared to those obtained with the Bayesian SPM using the SIR algorithm and equal weighting (Table 22).

	SPM (SIR, equal weighting)		**WinBUGS[1] (SSSPM, MCMC)**		**WinBUGS[2] (SSSPM, MCMC)**		**WinBUGS[1] (SSLRSG, MCMC)**		**WinBUGS[2] (SSLRSG, MCMC)**	
Parameter	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**	**EV**	**CV**
K (N_0)	9630	0.32	8386	1.15	1690	0.52	11850	1.19	3222	0.52
r	0.17	0.75	0.27	0.57	0.98	0.47	---	---	---	---
C_0	309	0.44	340	0.42	272	0.31	350	0.42	335	0.35
N_{2001}	6650	0.43	6585	1.49	227	0.70	9763	1.55	136	7.11
N_{2001}/K	0.68	0.26	0.69	0.31	0.15	0.77	0.63	0.47	0.02	2.59
MSC	378	0.68	445	1.16	327	0.14	658	1.44	194	0.27
z	---	---	---	---	---	---	0.61	0.31	0.60	0.17
s	---	---	---	---	---	---	0.84	0.07	0.84	0.05

[1] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for each series
[2] Using one MLE for q for each series, 1 σ^2, 1 τ^2 for all series

Table 48. Parameter estimates for Sandbar Updated and Baseline MLE models.

Parameter	Update Model	Baseline Model
m (net natural removals)	9.06 E-9	5.76 E-9
Commercial catchability	1.36 E-6	1.04 E-6
Recreational catchability	9.99 E-11	1.10 E-10
Population Size in 2001	2.83 E6	3.78 E6

Table 49. Annual estimates of fishing mortality and population size for Updated and Baseline MLE models for sandbar shark.

	Update Model				Baseline Model			
Year	$F_{commercial}$	$F_{recreational}$	F_{total}	N_{total}	$F_{commercial}$	$F_{recreational}$	F_{total}	N_{total}
1994	0.025412	0.005987	0.031399	3526600	0.019556	0.00661	0.026166	4549190
1995	0.02775	0.005849	0.033598	3415870	0.021355	0.006457	0.027812	4430160
1996	0.034399	0.005682	0.040081	3301110	0.026472	0.006273	0.032745	4306940
1997	0.022053	0.006178	0.028231	3168790	0.016971	0.006821	0.023792	4165910
1998	0.032228	0.005472	0.037699	3079340	0.024801	0.006041	0.030842	4066800
1999	0.016337	0.005085	0.021421	2963250	0.012572	0.005613	0.018185	3941370
2000	0.018671	0.006919	0.02559	2899770	0.014368	0.007639	0.022007	3869700

Table 50. Parameter estimates for Blacktip Update and Baseline MLE models.

Parameter	Update Model	Baseline Model
m (net natural removals)	5.78 E-7	3.38 E-7
Commercial catchability	5.42 E-7	2.00 E-6
Recreational catchability	2.14 E-10	8.18 E-10
Population Size in 2001	9.11 E6	1.99 E6

Table 51. Annual estimates of fishing mortality and population size for Update and Baseline MLE models for blacktip shark.

	Update Model				Baseline Model			
Year	$F_{commercial}$	$F_{recreational}$	F_{total}	N_{total}	$F_{commercial}$	$F_{recreational}$	F_{total}	N_{total}
1994	0.01014	0.012831	0.02297	10699600	0.037525	0.049064	0.086589	3728940
1995	0.011073	0.012534	0.023606	10453900	0.040978	0.047928	0.088906	3406060
1996	0.013726	0.012177	0.025903	10207100	0.050796	0.046566	0.097362	3103240
1997	0.008799	0.01324	0.022039	9942700	0.032565	0.050629	0.083194	2801100
1998	0.012859	0.011726	0.024585	9723580	0.04759	0.044841	0.092431	2568070
1999	0.006518	0.010896	0.017415	9484520	0.024124	0.041667	0.065791	2330700
2000	0.00745	0.014828	0.022277	9319360	0.027571	0.0567	0.084271	2177360

Table 52. Summary of sandbar shark runs with the age-structured production model (ASPM). "U" = Updated and "B" = Baseline models. Model runs used "all" CPUE indices, only fishery-dependent indices ("fd") or only fishery-independent indices ("fi"). F_H is historic level of fishing.

Model input	SB_U_all	SB_U_fd	SB_U_fi	SB_B_all	SB_B_fd	SB_B_fi
Age classes	18	18	18	18	18	18
Years	1986-2001	1986-2001	1986-2001	1981-2001	1981-2001	1981-2001
Seasons	12	12	12	12	12	12
Fecundity/Weight	Pups = 12	Pups = 12	Pups = 12	Pups = 12	Pups = 12	Pups = 12
Reproduction	Mid-year	Mid-year	Mid-year	Mid-year	Mid-year	Mid-year
Num. Catch Series	3	3	3	4	4	4
Num. CPUE Series	15	6	9	16	6	10
Output						
% Depletion	99.9	78.5	99.9	55.6		43.5
% $SSB_{current}/SSB_0$	0.1	21.5	0.1	44.4		56.5
% SSB_{msy}/SSB_0	38.5	32.5	34.8	32.2		33.5
$SSB_{current}$/SSBmsy	0.000332	0.661	0.000325	1.376		1.685
$F_{current}$/Fmsy	0.00441	2.45	0.00156	0.872		0.654
SSB_0	2.16 E12	2.09 E6	4.31 E12	3.83 E6		4.48 E6
SSB_{msy}	8.33 E11	6.78 E5	1.5 E12	1.24 E6		1.50 E6
$SSB_{current}$	2.77 E8	4.48 E5	4.86 E8	1.70 E6		2.53 E6
$F_{current}$	0.0002	0.196	0.0000998	0.0803		0.055
F_{msy}	0.046	0.080	0.064	0.092		0.084
F_H	0.0495	2.04 E-8	0.0712	1.34 E-8		1.87 E-8
$N_{current}$	7.04 E8	7.06 E5	1.44 E9	2.11 E6		3.11 E6
Estimated steepness	0.371	0.540	0.463	0.544		0.501
Pup Survival	0.639	0.595	0.787	0.611		0.604
M	0.177	0.136	0.167	0.137		0.145
R_0	5.85 E11	2.64 E5	9.85 E11	4.90 E5		6.74 E5
Virgin Spawner per Recruit	3.70	7.91	4.38	7.82		6.64
MSY Spawner per Recruit	2.39	3.70	2.35	3.63		3.33
Spawning Potential Ratio at MSY	0.645	0.468	0.537	0.464		0.501

Table 53. Summary of blacktip shark runs with the age-structured production model (ASPM). "U" = Updated and "B" = Baseline models. Model runs used "all" CPUE indices, only fishery-dependent indices ("fd") or only fishery-independent indices ("fi"). F_H is historic level of fishing.

Model input	**BT_U_all**	BT_U_fd	BT_U_fi	**BT_B_all**	**BT_B_fd**	**BT_B_fi**
Age classes	14	14	14	14	14	14
Years	1986-2001	1986-2001	1986-2001	1981-2001	1981-2001	1981-2001
Seasons	12	12	12	12	12	12
Fecundity/Weight	Pups = 5	Pups = 5	Pups = 5	Pups = 5	Pups = 5	Pups = 5
Reproduction	Mid-year	Mid-year	Mid-year	Mid-year	Mid-year	Mid-year
Num. Catch Series	3	3	3	4	4	4
Num. CPUE Series	14	6	8	14	6	8
Output						
% Depletion	61.6	67.3	51.1	27.2	14.4	35.7
% $SSB_{current}/SSB_0$	38.4	32.7	46.9	74.2	85.6	64.3
% SSB_{msy}/SSB_0	42.0	41.4	44.2	44.7	43.5	31.9
$SSB_{current}$/SSBmsy	0.914	0.789	1.061	1.661	1.968	2.014
$F_{current}$/Fmsy	1.39	1.718	1.16	0.130	0.0117	0.026
SSB_0	4.58 E6	4.14 E6	5.98 E6	4.25 E7	3.45 E8	9.07 E7
SSB_{msy}	1.92 E6	1.71 E6	2.64 E6	1.90 E7	1.50 E8	2.90 E7
$SSB_{current}$	1.76 E6	1.35 E6	2.80 E6	3.16 E7	2.95 E7	5.84 E7
$F_{current}$	0.161	0.210	0.0949	0.00752	0.00088	0.00701
F_{msy}	0.116	0.122	0.082	0.058	0.075	0.268
F_H	0.01	0.01	0.01	0.011	0.01	0.117*
$N_{current}$	2.16 E6	1.64 E6	3.65 E6	4.20 E7	3.72 E8	5.94 E7
Estimated steepness	0.330	0.338	0.287	0.267	0.289	0.588
Pup Survival	0.487	0.490	0.472	0.462	0.473	0.749
M	0.198	0.195	0.214	0.221	0.213	0.143
R_0	1.13 E6	9.91 E5	1.75 E6	1.35 E7	1.00 E8	1.19 E7
Virgin Spawner per Recruit	4.05	4.17	3.41	3.16	3.44	7.63
MSY Spawner per Recruit	2.89	2.92	2.69	2.61	2.69	3.35
Spawning Potential Ratio at MSY	0.714	0.701	0.789	0.826	0.782	0.439

Table 54. Sandbar shark projections from the ASPM model. Probabilities are the number of bootstraps out of 500 that were greater than or equal to the reference spawning stock biomass level (B_{2000}, B_{msy}, or $(1\text{-}M)B_{msy}$).

	Year--->	2010	2010	2010	2020	2020	2020	2030	2030	2030
MODEL	**TAC**[1]	**P(B>B$_{2000}$)**	**P(B>B$_{msy}$)**	**P(B>(1-M)B$_{msy}$)**	**P(B>B$_{2000}$)**	**P(B>B$_{msy}$)**	**P(B>(1-M)B$_{msy}$)**	**P(B>B$_{2000}$)**	**P(B>B$_{msy}$)**	**P(B>(1-M)B$_{msy}$)**
Updated	0	1	0	0	1	0	0	1	0	0
(all series)	0.5	1	0	0	1	0	0	1	0	0
	0.8	1	0	0	1	0	0	1	0	0
	1.0	1	0	0	1	0	0	1	0	0
	1.2	1	0	0	1	0	0	1	0	0
	1.5	1	0	0	1	0	0	1	0	0
Updated	0	1	1	1	1	1	1	1	1	1
(F-D series	0.5	1	0	0.654	0.978	0.792	0.932	0.992	0.946	0.982
only)	0.8	0.076	0	0	0.542	0.238	0.396	0.622	0.404	0.544
	1.0	0	0	0	0.2	0.064	0.154	0.196	0.09	0.156
	1.2	0	0	0	0.052	0.014	0.03	0.038	0.012	0.03
	1.5	0	0	0	0.002	0	0.002	0.002	0	0.002
Updated	0	1	0	0	1	0	0	1	0	0
(F-I series	0.5	1	0	0	1	0	0	1	0	0
only)	0.8	1	0	0	1	0	0	1	0	0
	1.0	1	0	0	1	0	0	1	0	0
	1.2	1	0	0	1	0	0	1	0	0
	1.5	1	0	0	1	0	0	1	0	0
Baseline	0	1	1	1	1	1	1	1	1	1
(all series)	0.5	1	1	1	1	1	1	0.998	1	1
	0.8	1	1	1	1	1	1	0.964	1	1
	1.0	1	1	1	0.982	1	1	0.894	1	1
	1.2	1	1	1	0.896	1	1	0.812	0.998	1
	1.5	0.992	1	1	0.608	1	1	0.598	0.98	0.996
Baseline	0	1	1	1	1	1	1	1	1	1
(F-I series	0.5	1	1	1	1	1	1	0.972	1	1
only)	0.8	1	1	1	0.994	1	1	0.91	1	1
	1.0	1	1	1	0.964	1	1	0.848	1	1
	1.2	1	1	1	0.868	1	1	0.77	1	1
	1.5	1	1	1	0.644	1	1	0.61	1	1

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch

Table 55. Blacktip shark projections from the ASPM model. Probabilities are the number of bootstraps out of 500 that were greater than or equal to the reference spawning stock biomass level (B_{2000}, B_{msy}, or $(1\text{-}M)B_{msy}$).

	Year--->	2010	2010	2010	2020	2020	2020	2030	2030	2030
MODEL	**TAC**[1]	**P(B>B_{2000})**	**P(B>B_{msy})**	**P(B>(1-M)B_{msy})**	**P(B>B_{2000})**	**P(B>B_{msy})**	**P(B>(1-M)B_{msy})**	**P(B>B_{2000})**	**P(B>B_{msy})**	**P(B>(1-M)B_{msy})**
Updated	0	0.974	0.93	1	0.996	0.992	1	0.998	0.998	1
(all series)	0.5	0.628	0.538	0.936	0.724	0.682	0.894	0.82	0.79	0.92
	0.8	0.376	0.264	0.714	0.422	0.376	0.582	0.424	0.382	0.568
	1.0	0.206	0.156	0.524	0.218	0.196	0.364	0.19	0.162	0.27
	1.2	0.128	0.076	0.35	0.124	0.096	0.186	0.066	0.064	0.108
	1.5	0.038	0.024	0.152	0.03	0.02	0.056	0.014	0.014	0.026
Updated	0	0.984	0.724	0.99	0.998	0.982	1	1	0.994	1
(F-D series	0.5	0.566	0.178	0.616	0.672	0.47	0.7	0.762	0.626	0.772
only)	0.8	0.228	0.054	0.28	0.272	0.16	0.292	0.254	0.16	0.266
	1.0	0.128	0.016	0.142	0.128	0.06	0.138	0.076	0.046	0.078
	1.2	0.048	0.006	0.058	0.036	0.012	0.038	0.024	0.014	0.026
	1.5	0.008	0.002	0.008	0.002	0	0.002	0.002	0.002	0.002
Updated	0	0.894	0.98	1	0.97	0.988	1	0.986	0.994	1
(F-I series	0.5	0.622	0.816	0.998	0.71	0.796	0.974	0.8	0.868	0.956
only)	0.8	0.468	0.636	0.972	0.5	0.598	0.842	0.564	0.636	0.802
	1.0	0.362	0.536	0.938	0.386	0.468	0.704	0.372	0.452	0.642
	1.2	0.242	0.414	0.854	0.26	0.346	0.564	0.228	0.272	0.448
	1.5	0.154	0.246	0.71	0.146	0.186	0.356	0.086	0.106	0.2
Baseline	0	1	1	1	0.782	1	1	0.82	0.996	1
(all series)	0.5	1	1	1	0.76	1	1	0.796	0.996	1
	0.8	1	1	1	0.742	1	1	0.77	0.996	1
	1.0	1	1	1	0.726	1	1	0.758	0.996	1
	1.2	1	1	1	0.712	1	1	0.74	0.994	1
	1.5	1	1	1	0.696	1	1	0.724	0.988	1

[1] Total Allowable Catch policy option expressed as a proportion of the reported 2000 catch

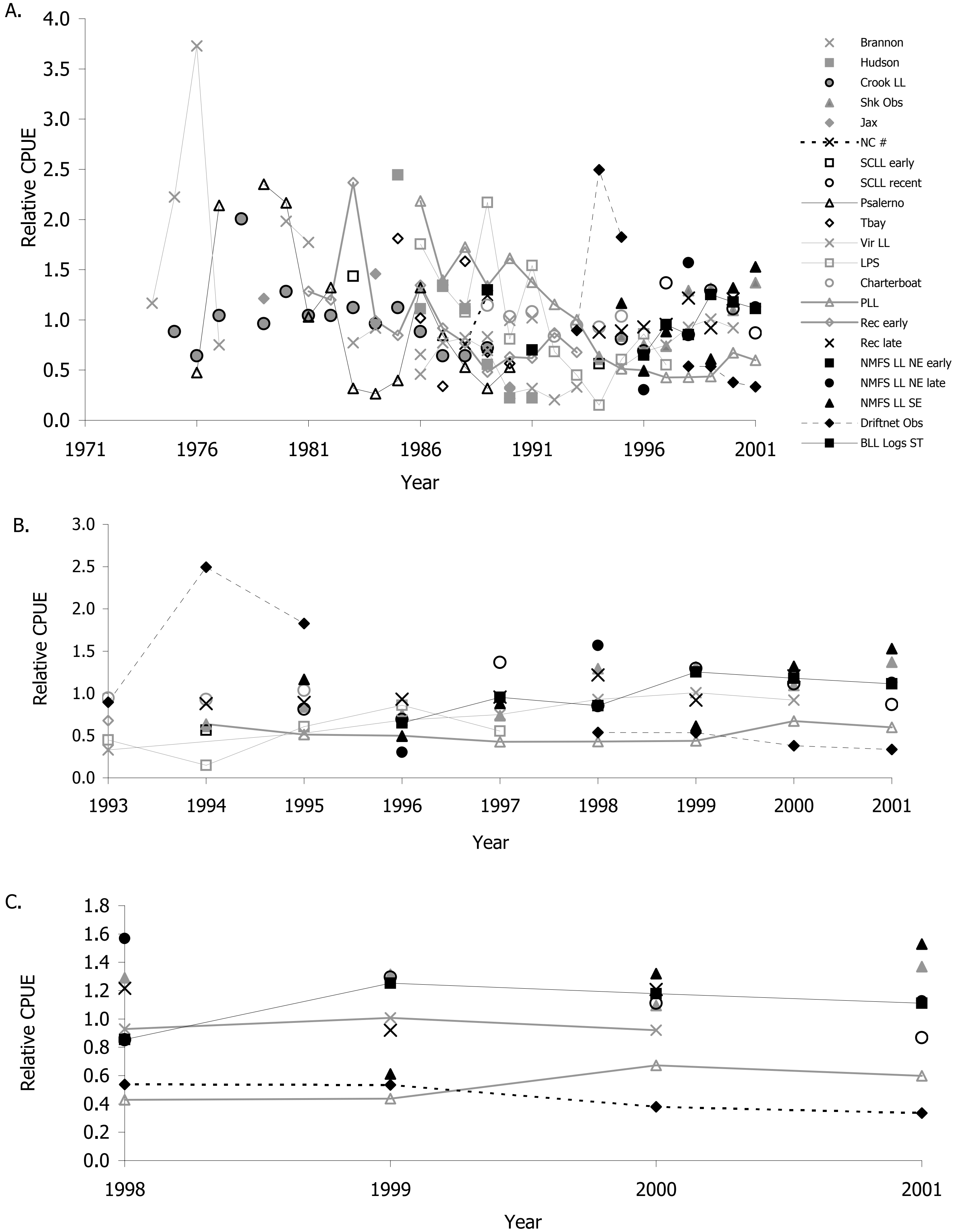


Figure 1. Large coastal shark complex CPUE series: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

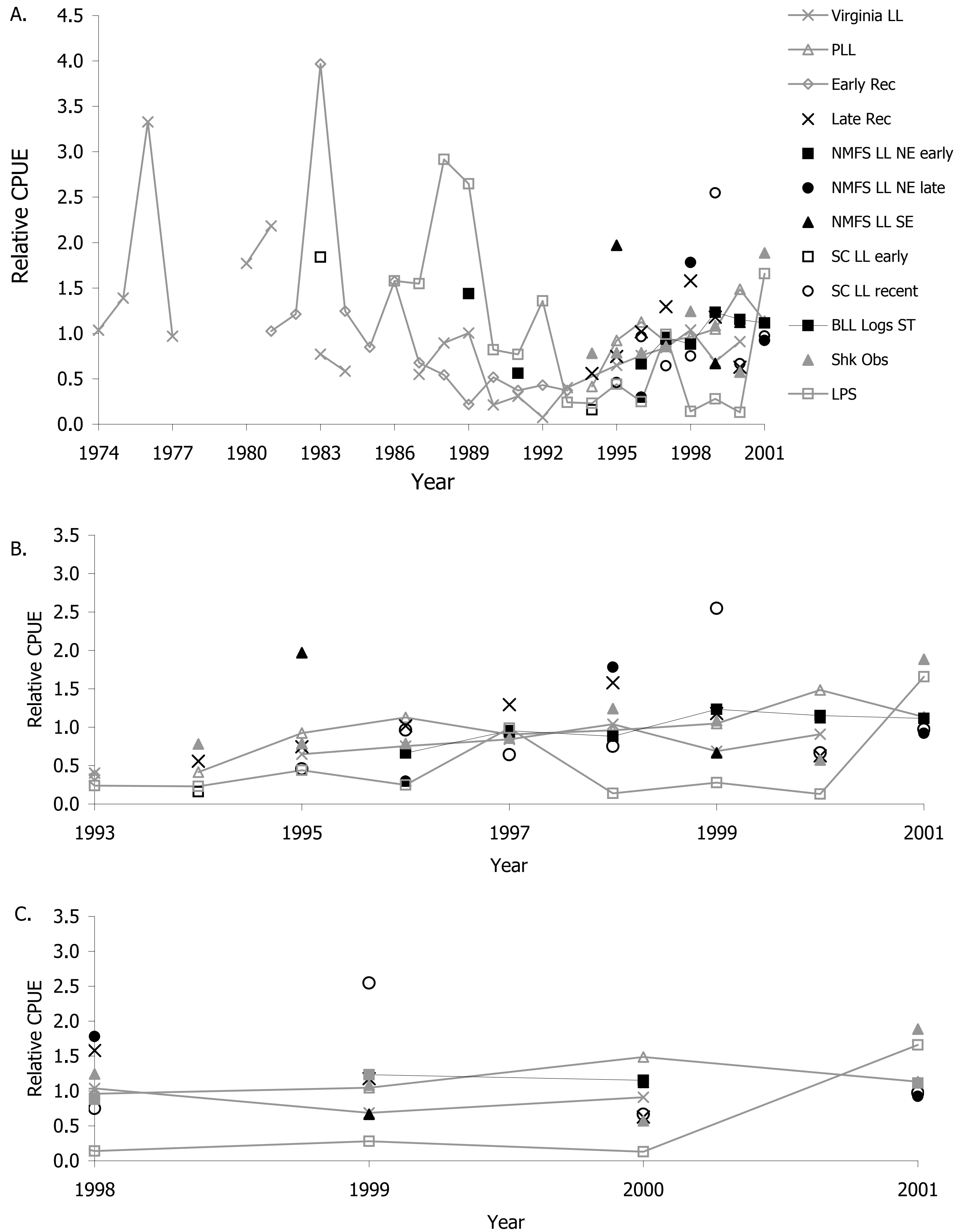


Figure 2. Sandbar shark CPUE series: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

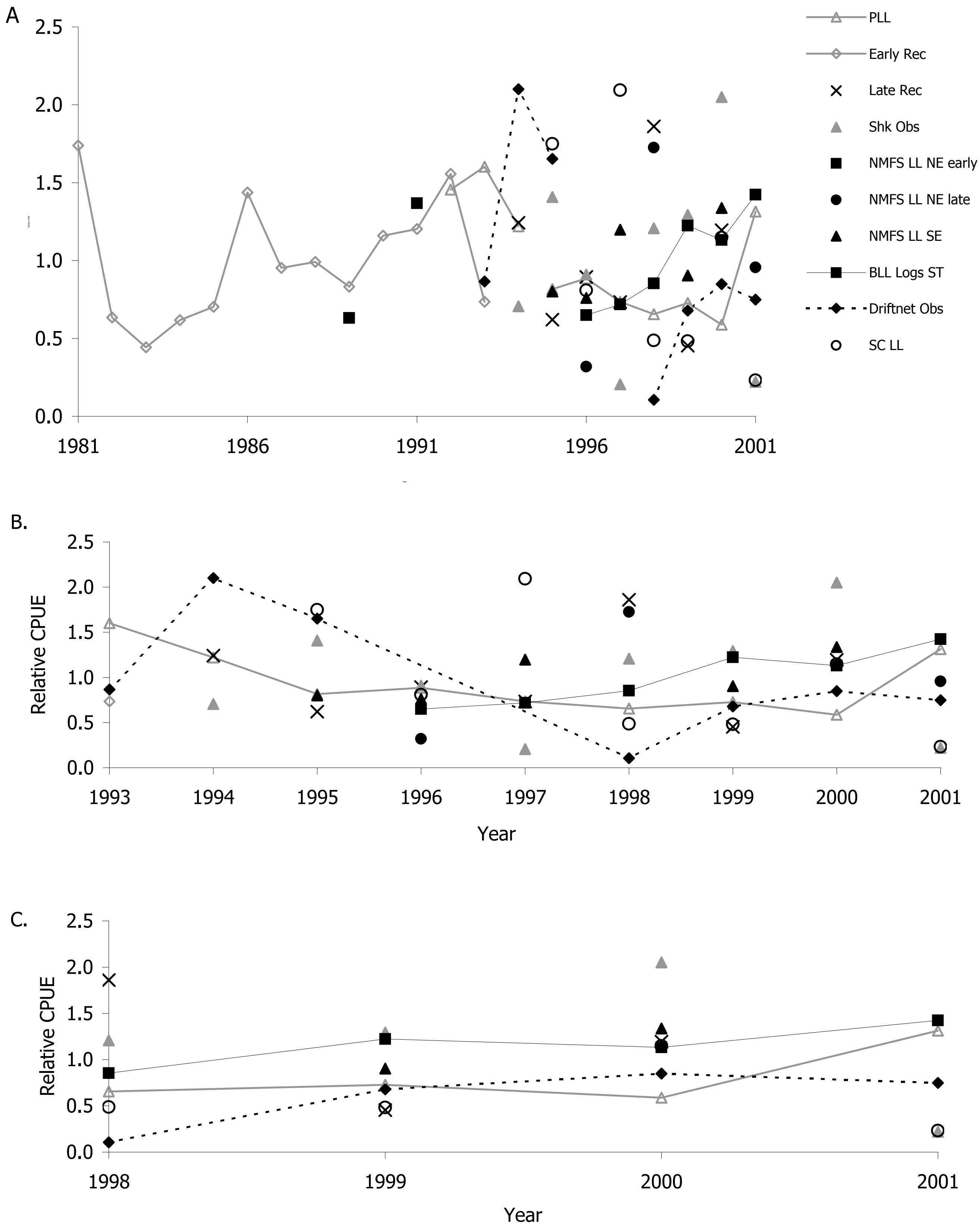


Figure 3. Blacktip shark CPUE series: A) 1974-2001, B) 1993-2001, C) 1998-2001.
Series are scaled (divided by the mean) to appear on a common scale.

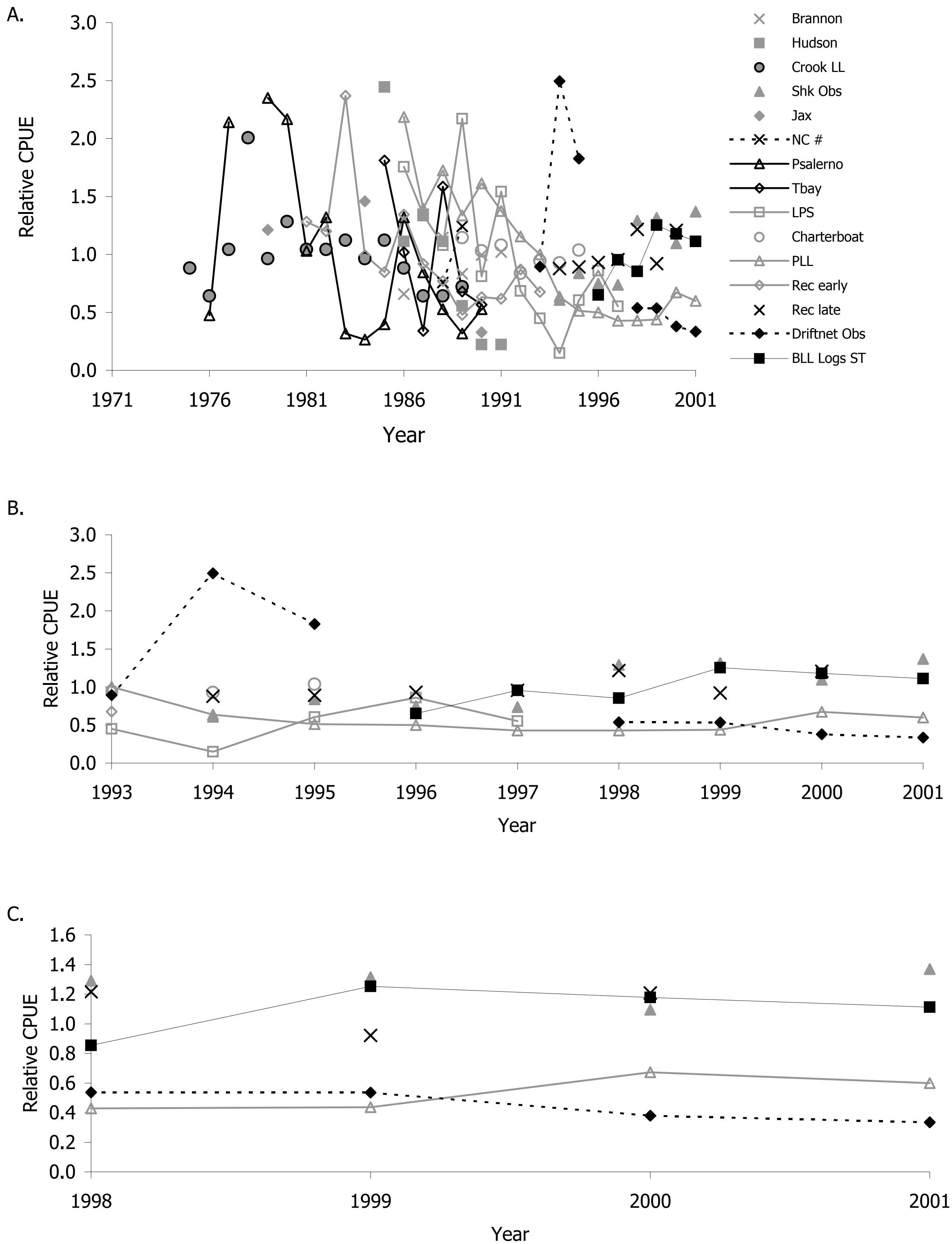


Figure 4. Fishery-dependent CPUE series for the large coastal shark complex: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

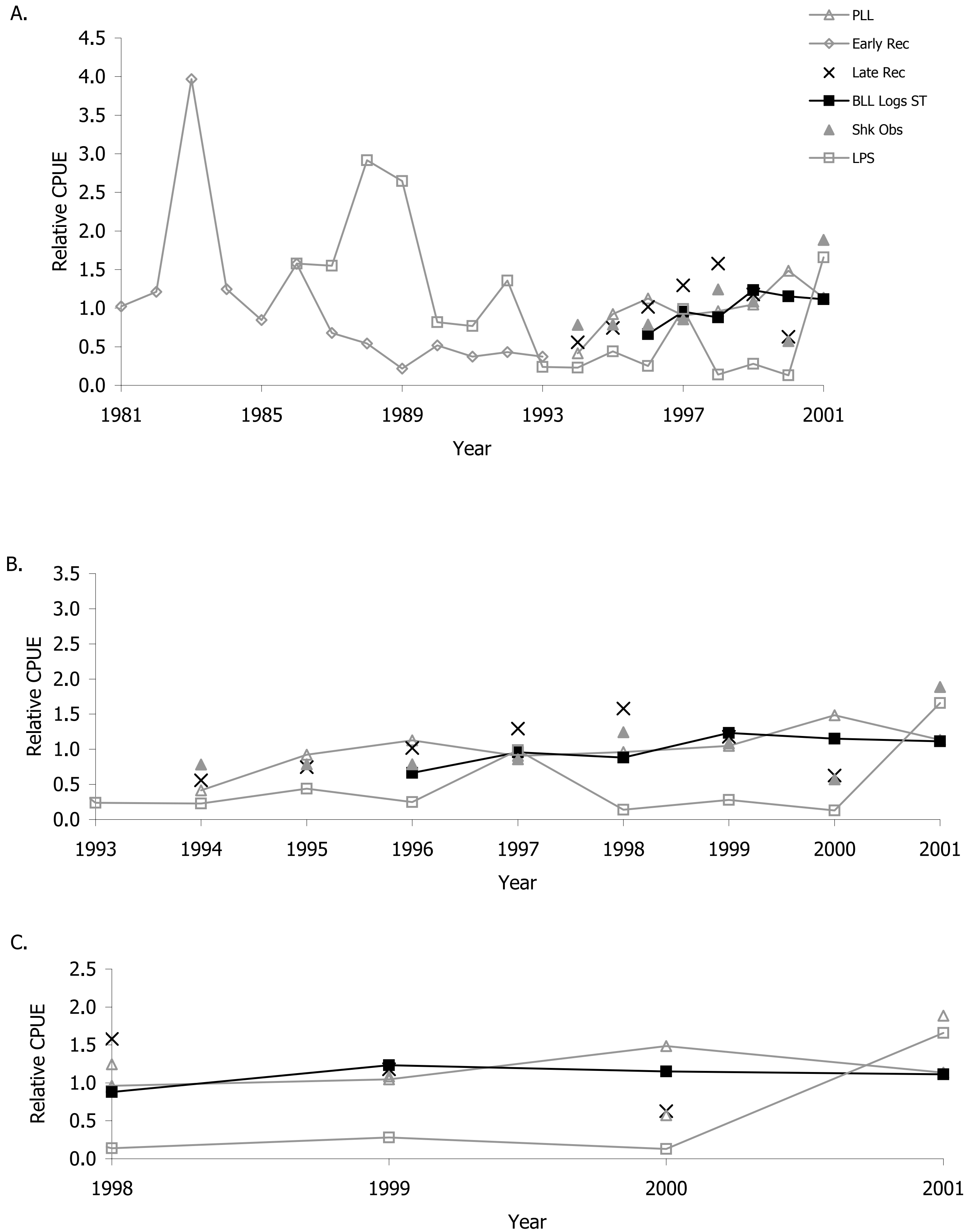


Figure 5. Fishery-dependent CPUE series for the sandbar shark: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

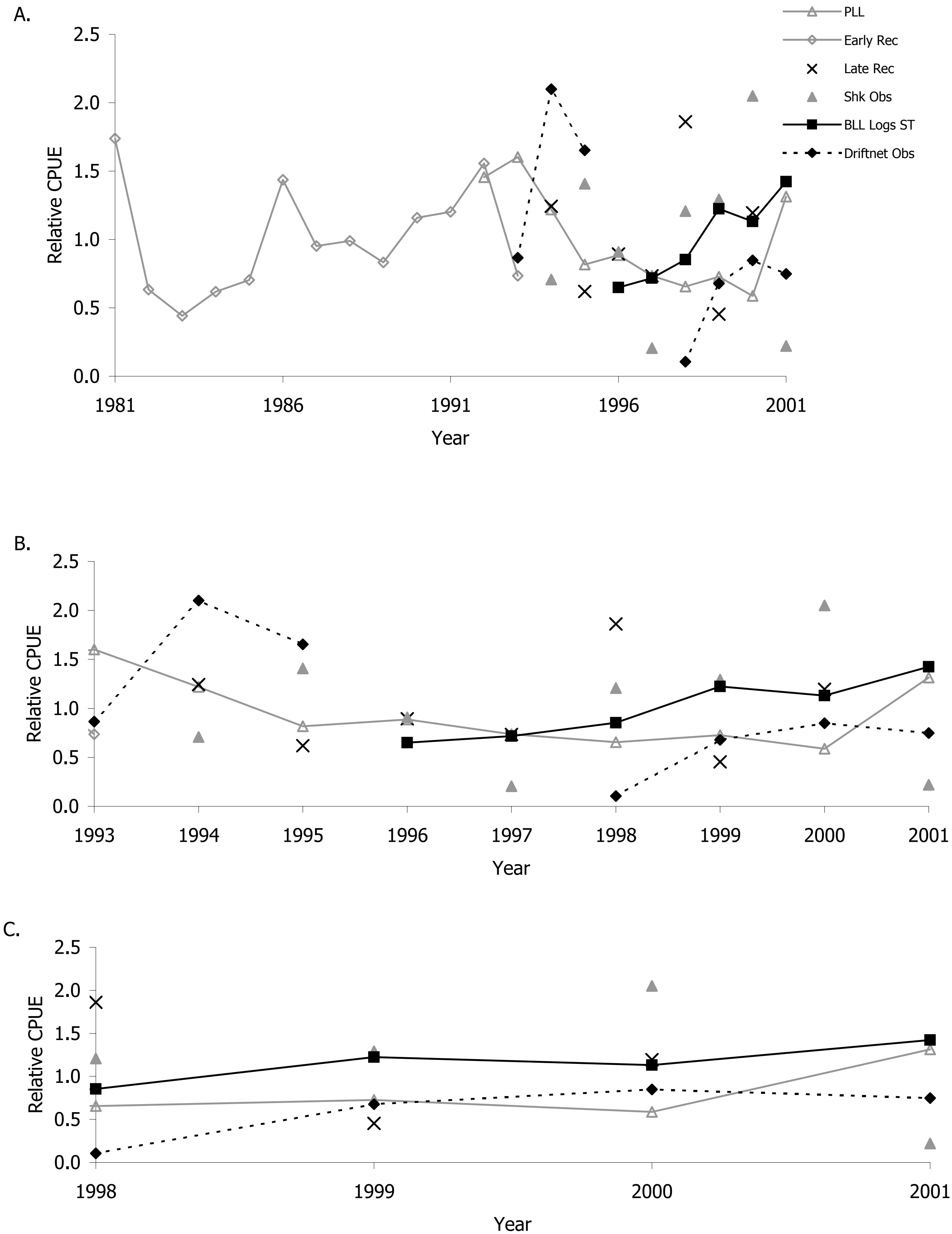


Figure 6. Fishery-dependent CPUE series for the blacktip shark: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

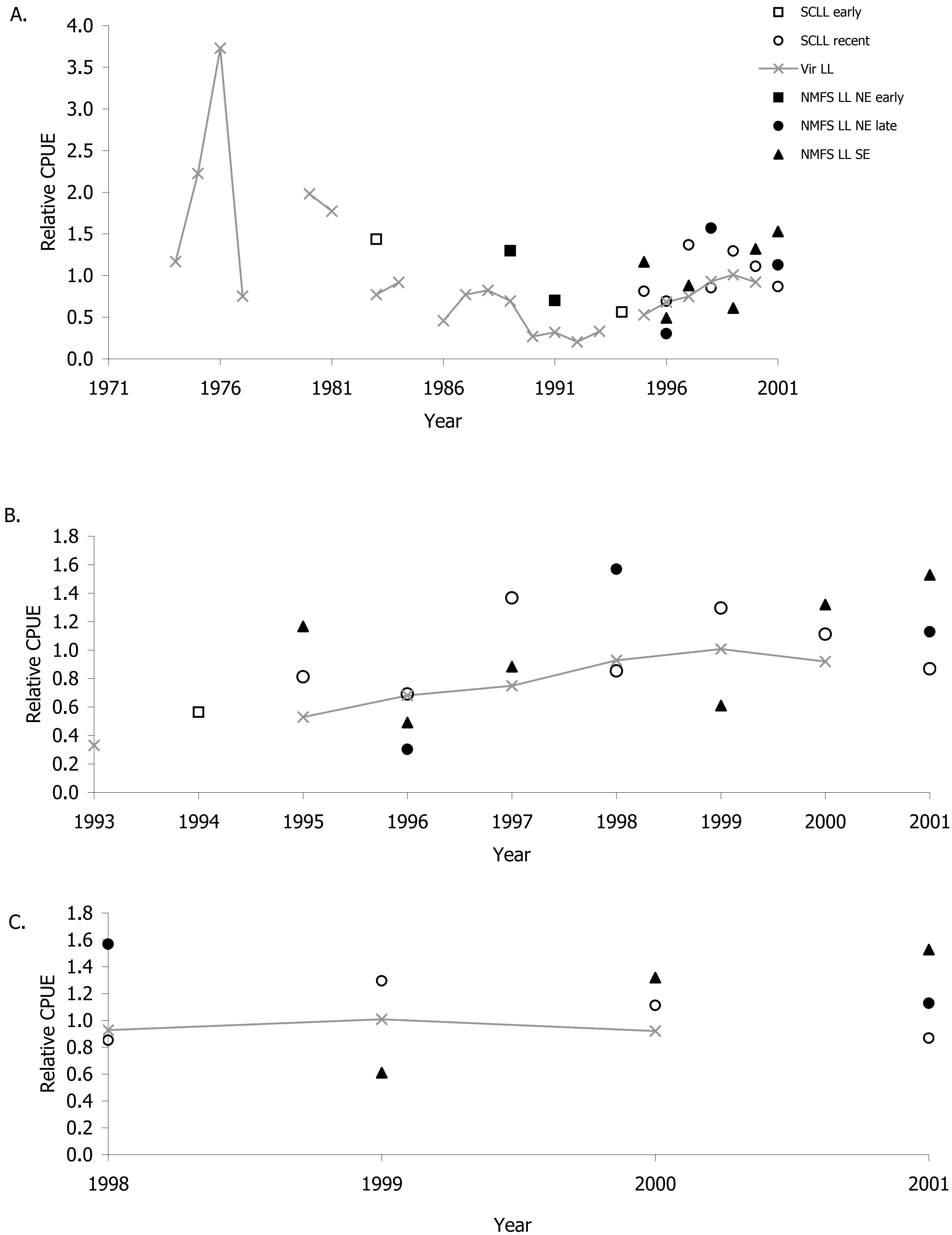


Figure 7. Fishery-independent CPUE series for the large coastal shark complex: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

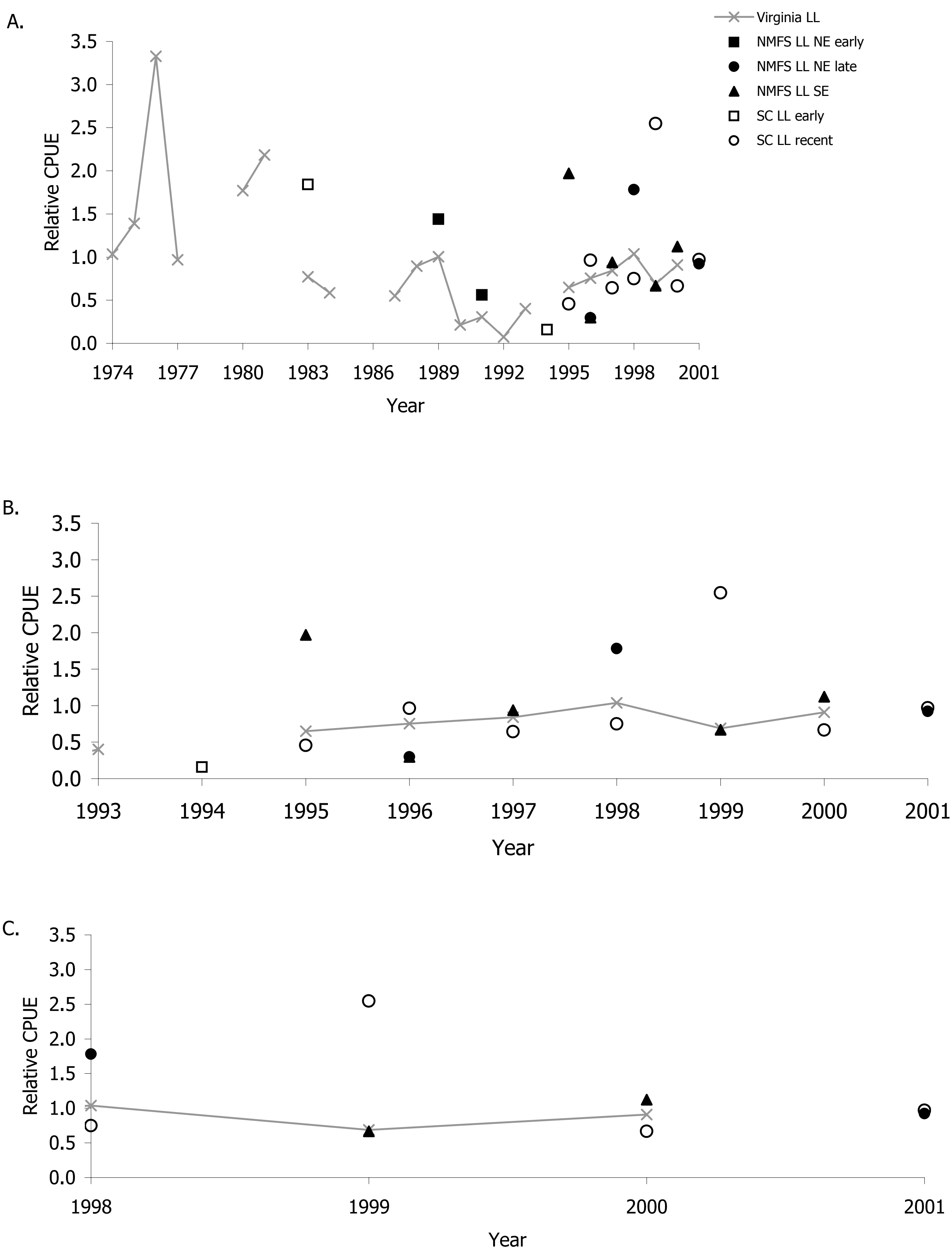


Figure 8. Fishery-independent CPUE series for the sandbar shark: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

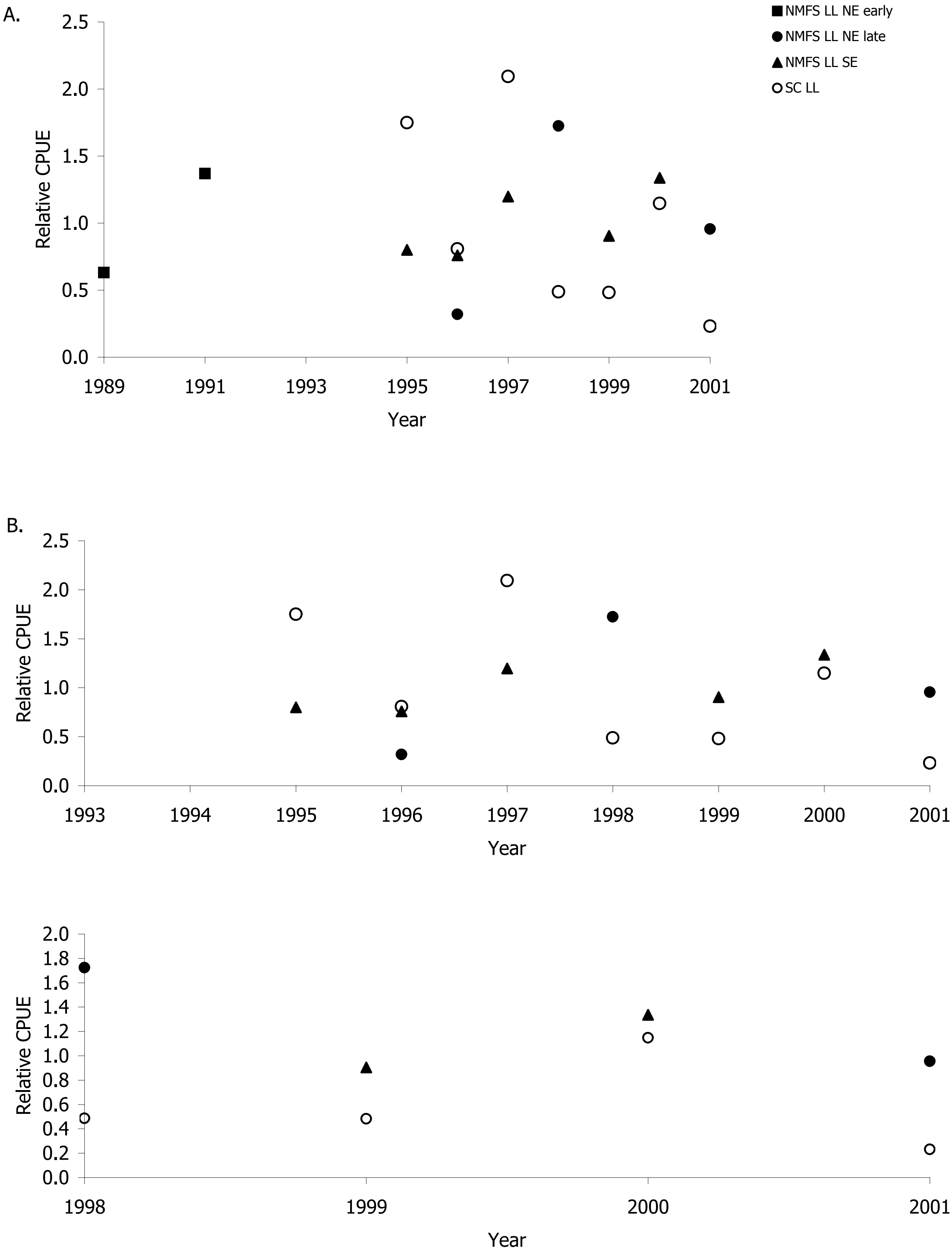


Figure 9. Fishery-independent CPUE series for the blacktip shark: A) 1974-2001, B) 1993-2001, C) 1998-2001. Series are scaled (divided by the mean) to appear on a common scale.

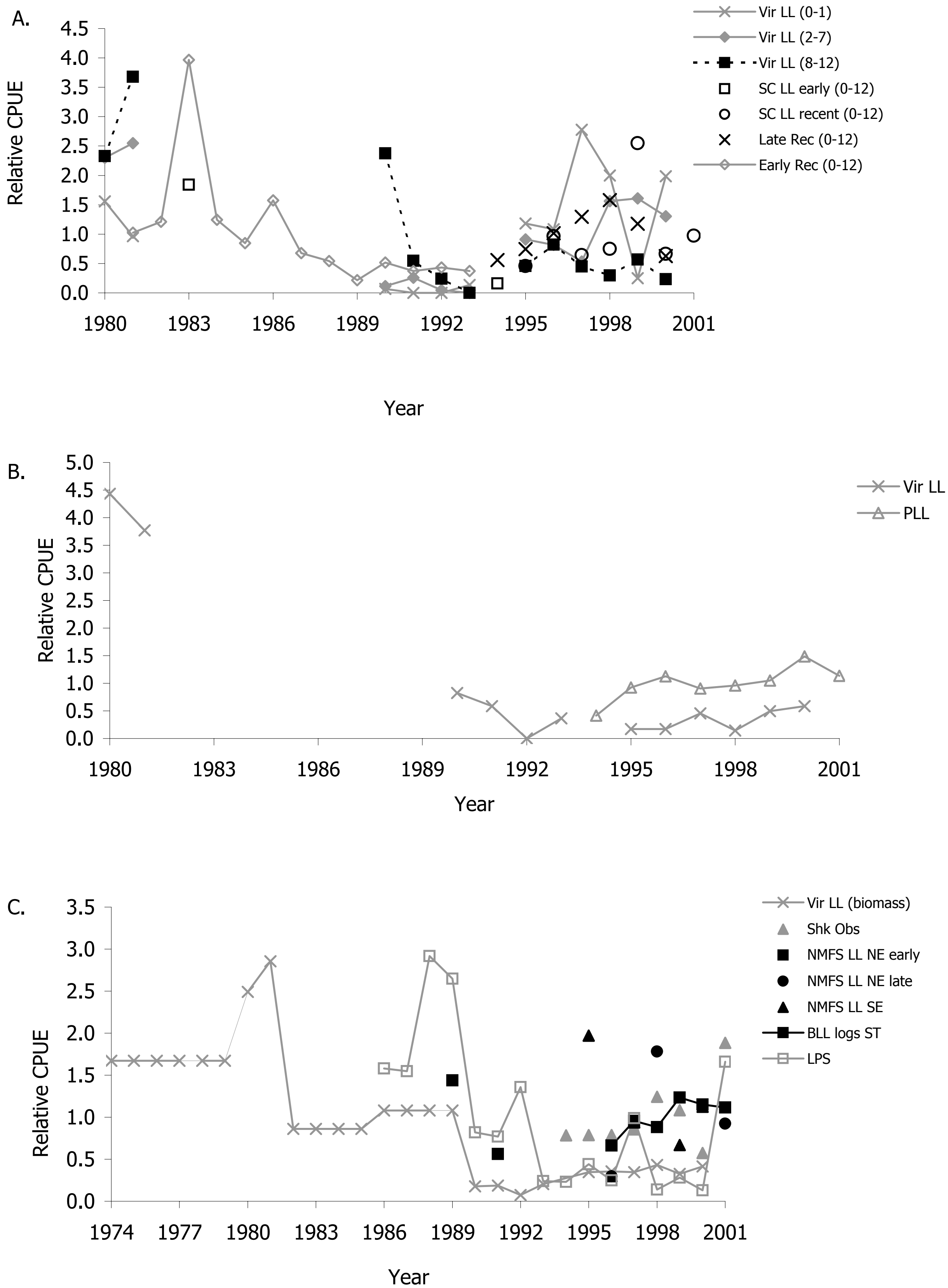


Figure 10. Age-specific CPUE series for the sandbar shark: A) Juveniles (Ages 0-12), B) Adults (Ages 13 and older), C) All ages combined.

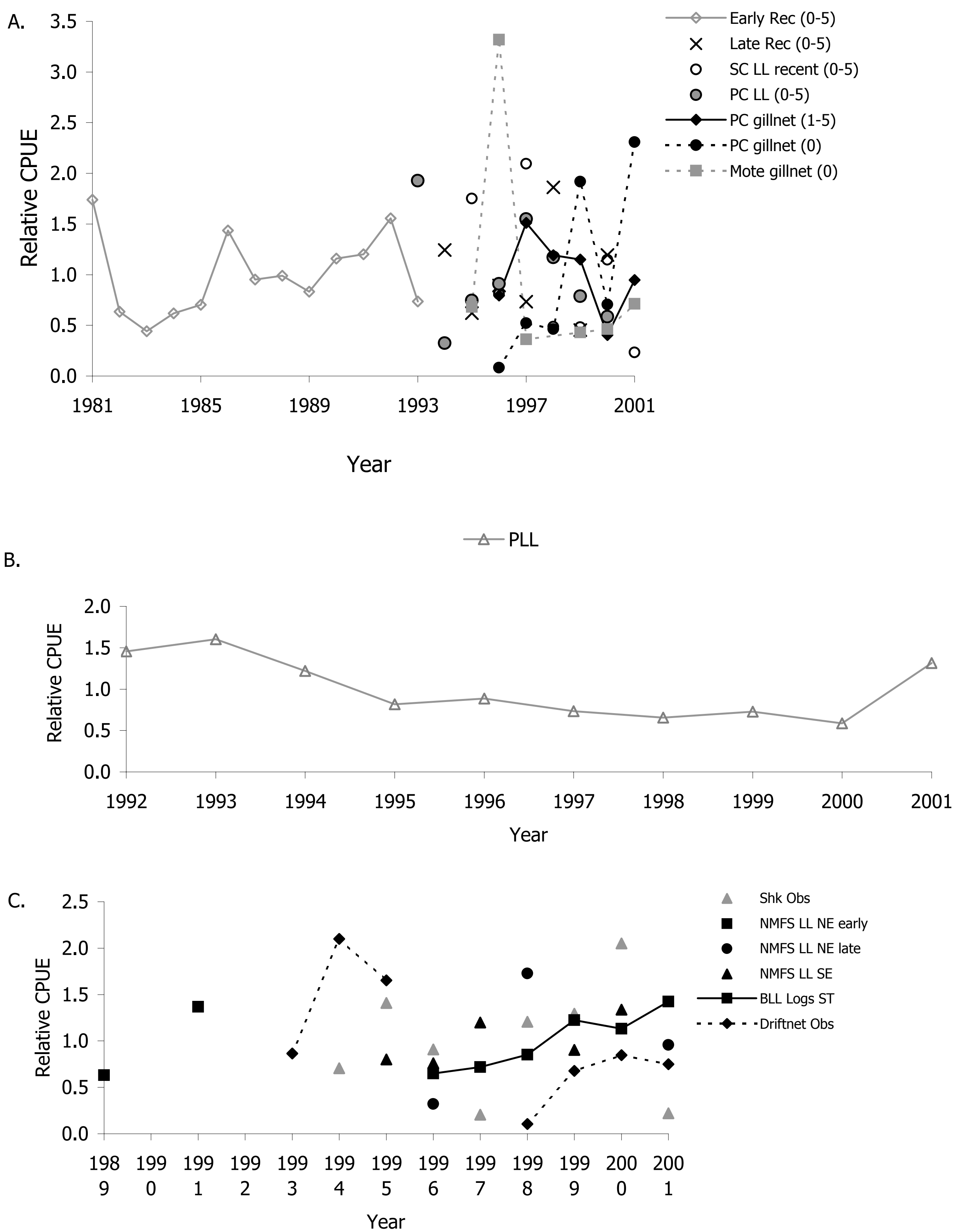


Figure 11. Age-specific CPUE series for the blacktip shark: A) Juveniles (Ages 0-5), B) Adults (Ages 6 and older), C) All ages combined.

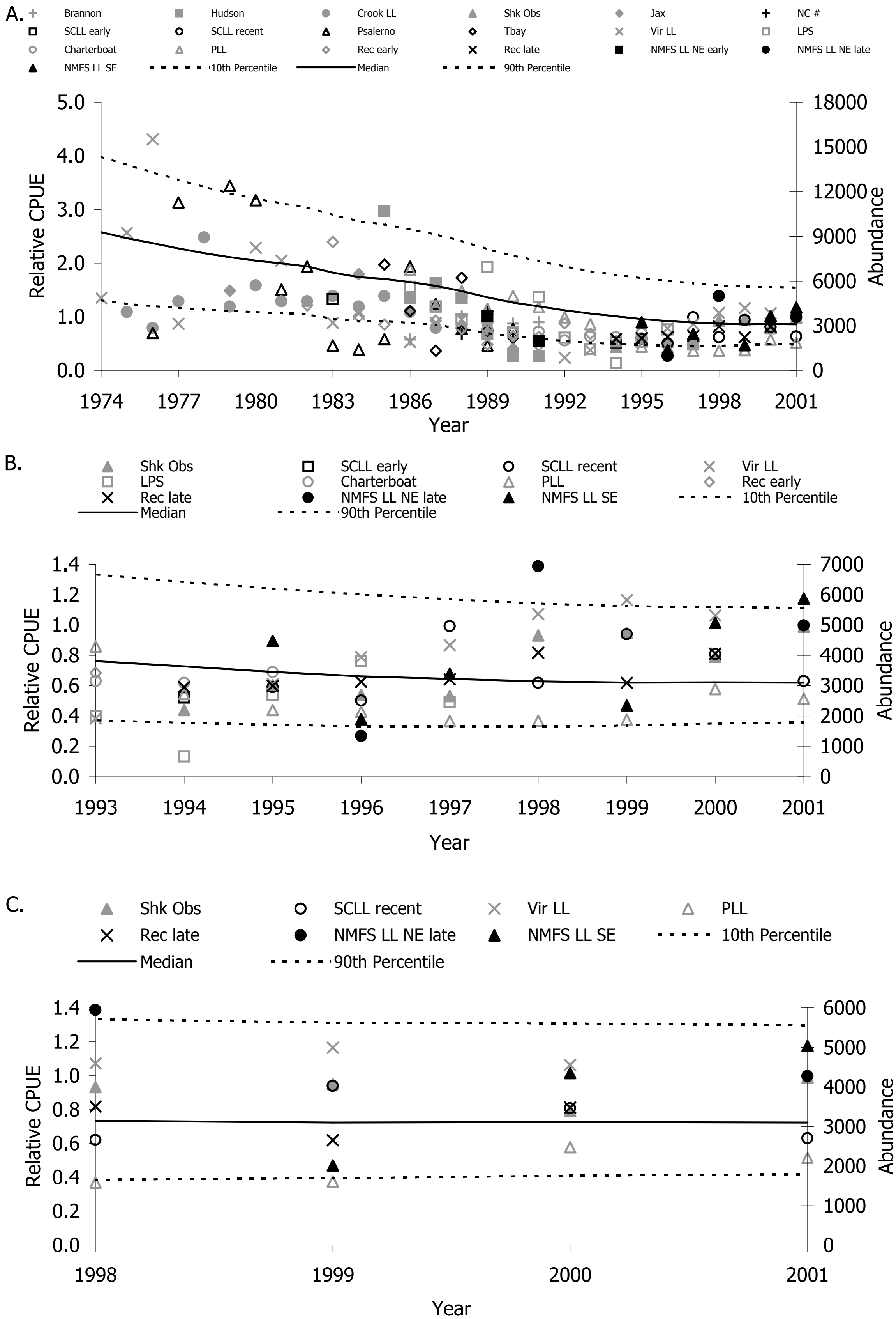


Figure 12. Abundance of the large coastal shark complex predicted by the surplus production model fitted to the catch and CPUE series for the updated scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

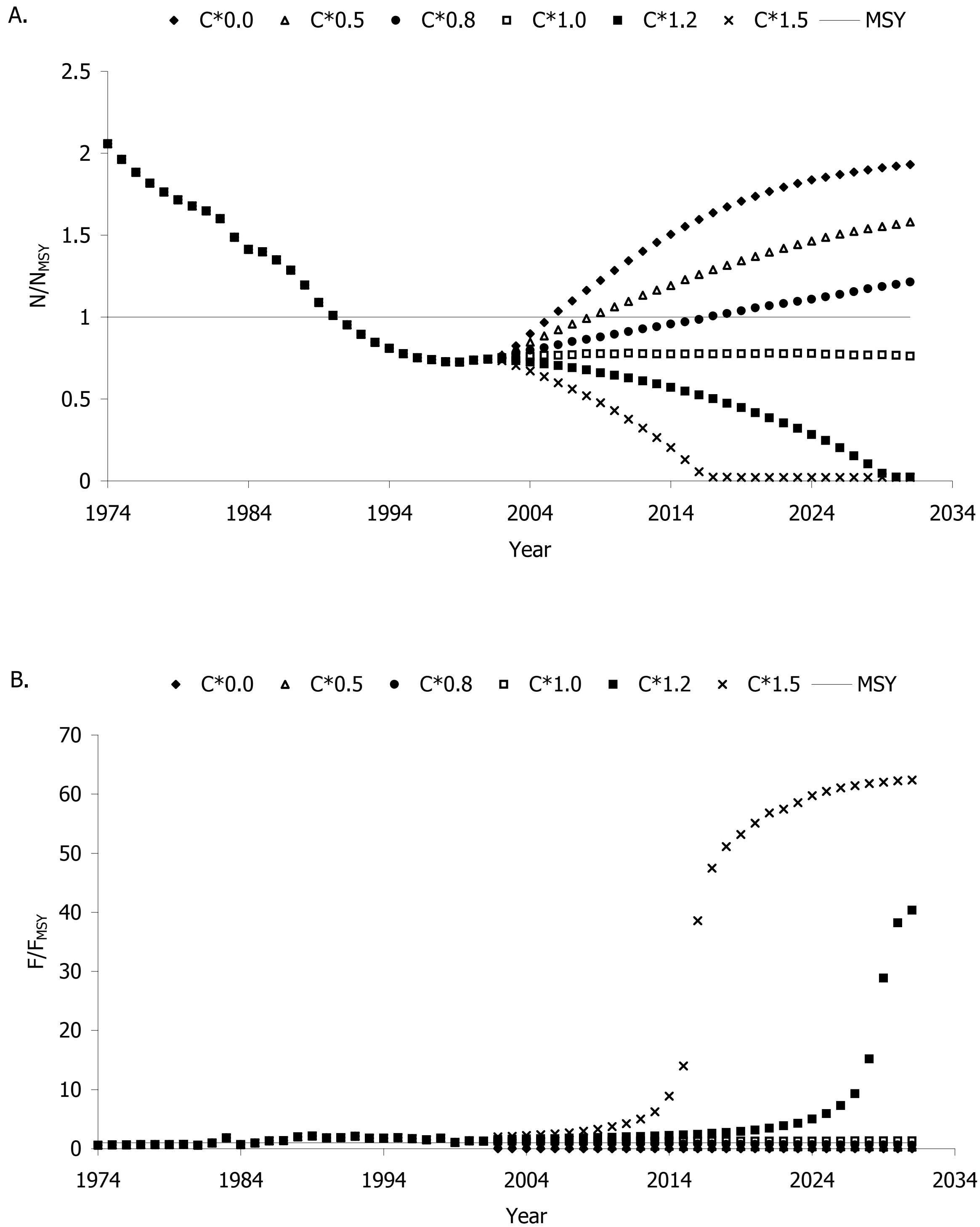


Figure 13. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the large coastal shark complex under the updated scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

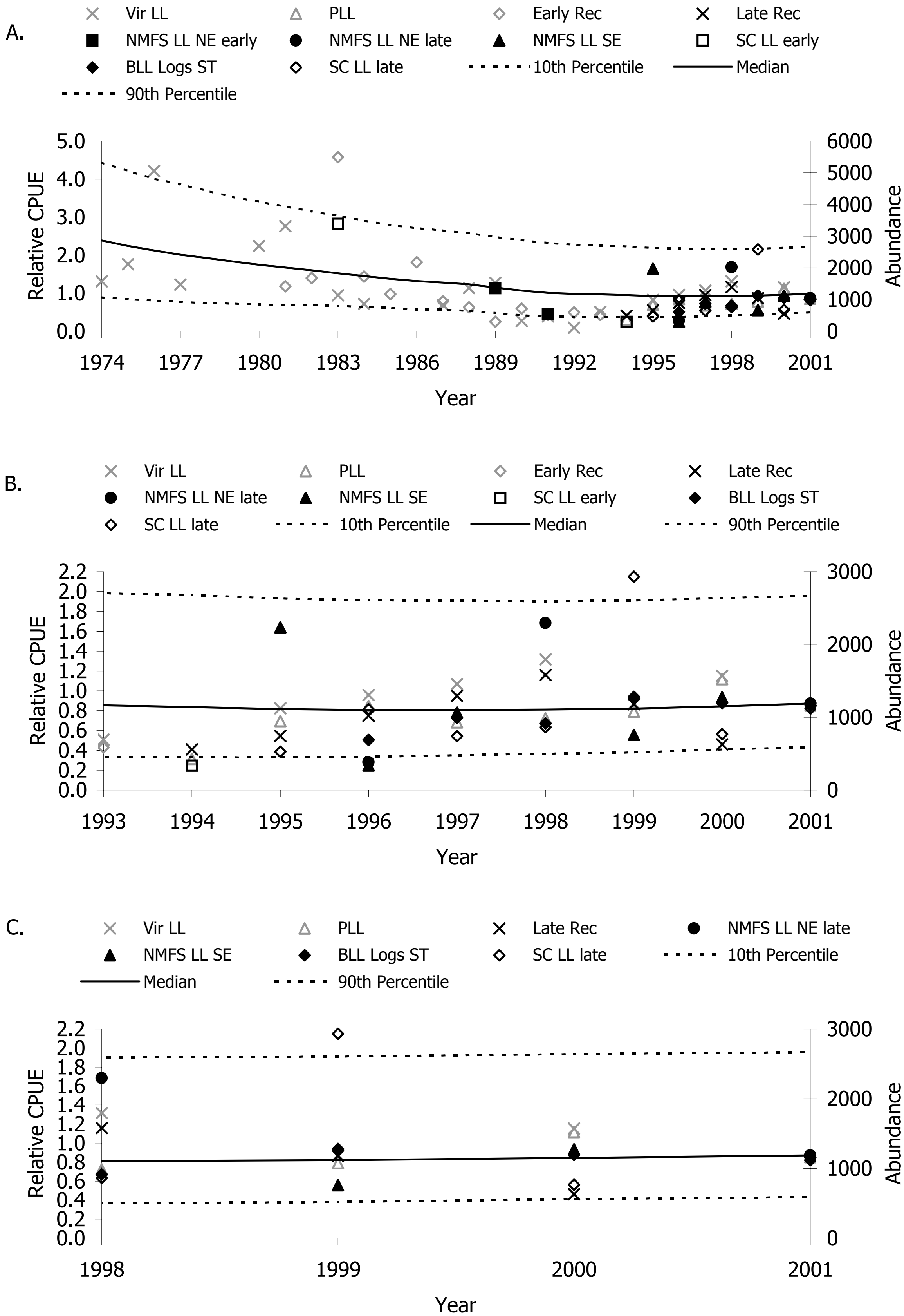
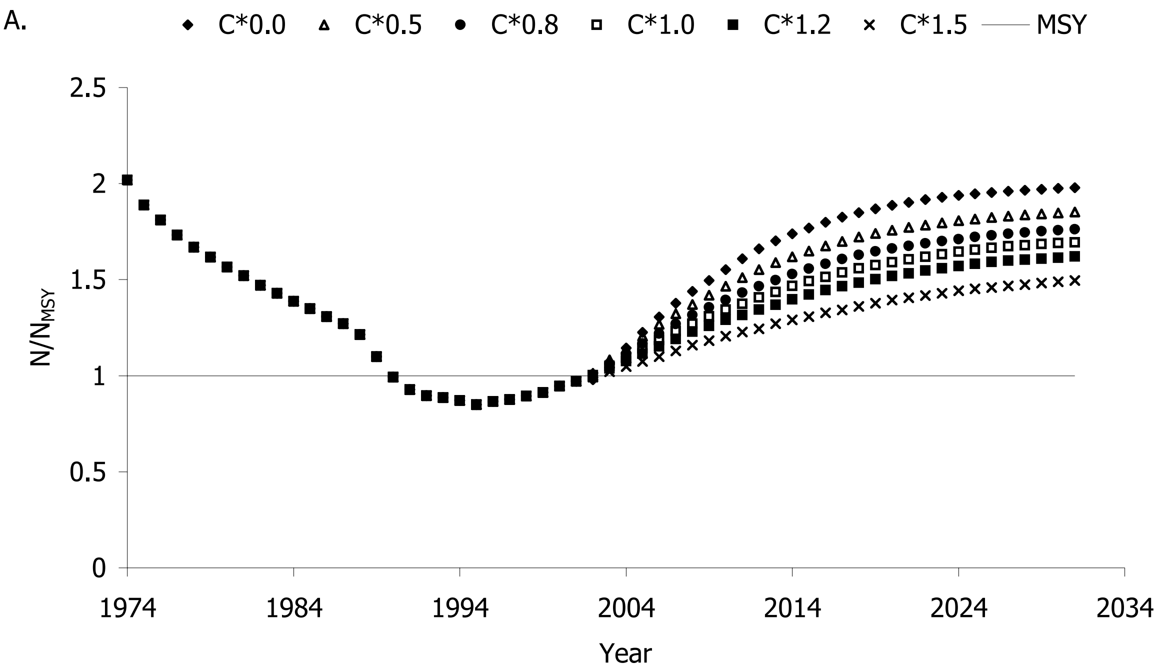


Figure 14. Abundance of the sandbar shark predicted by the surplus production model fitted to the catch and CPUE series for the updated scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

A.



B.

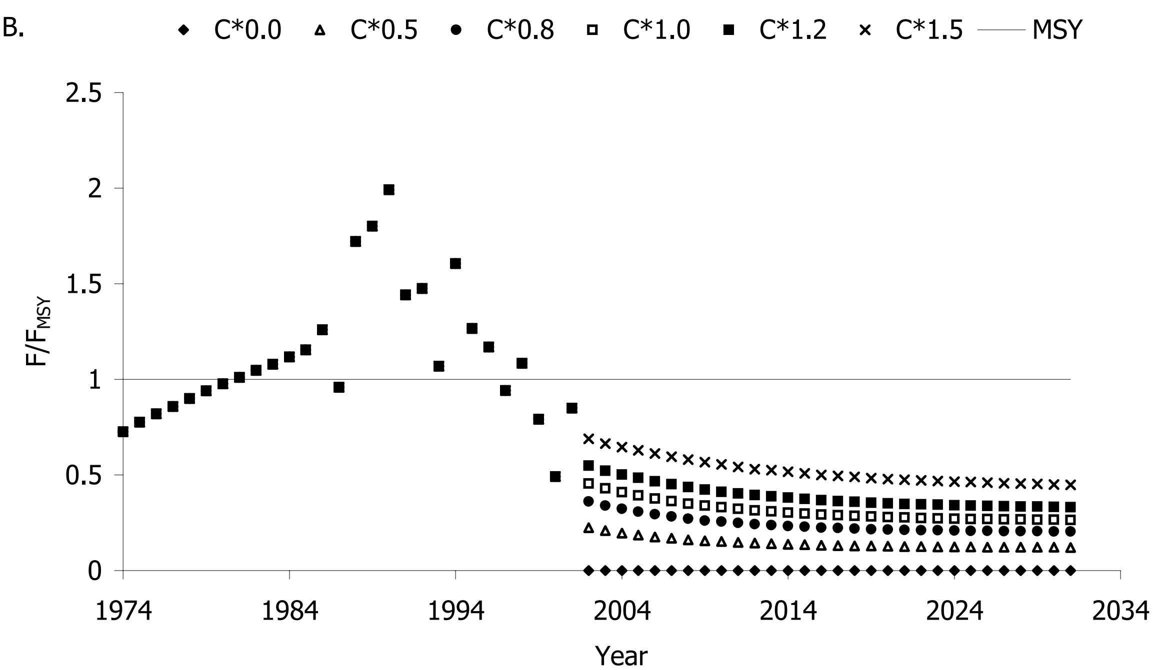


Figure 15. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the sandbar shark under the updated scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

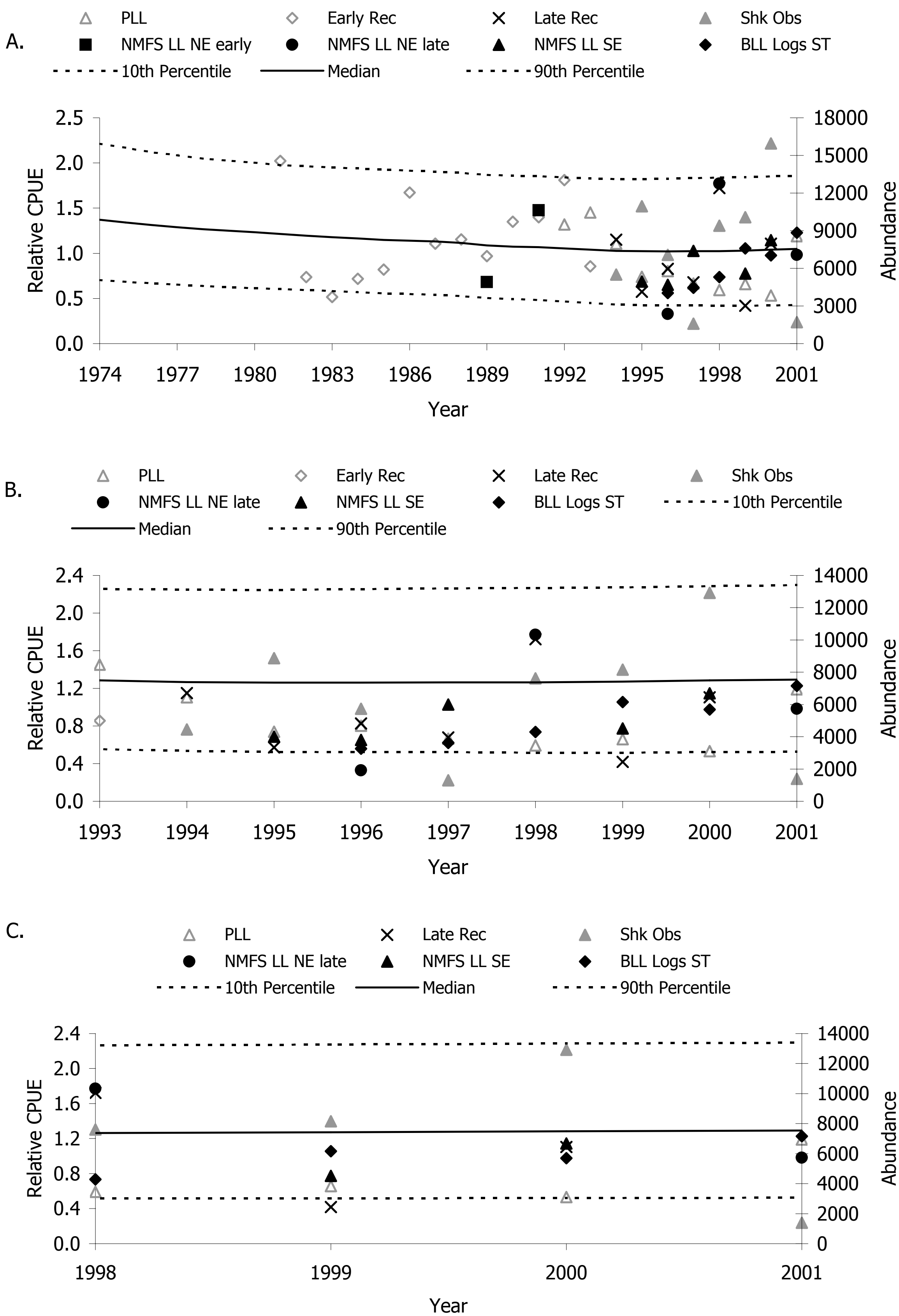


Figure 16. Abundance of the blacktip shark predicted by the surplus production model fitted to the catch and CPUE series for the updated scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

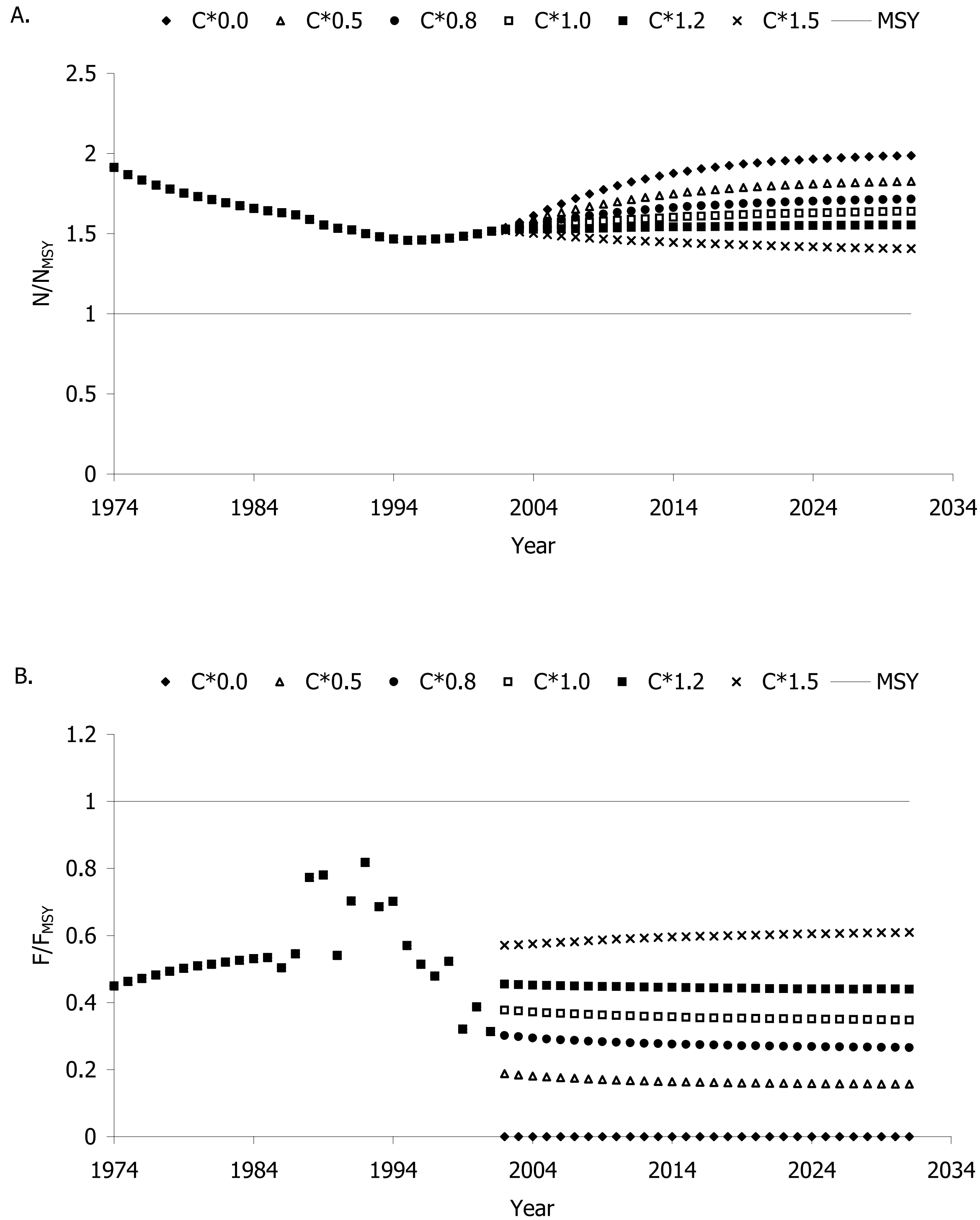


Figure 17. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the blacktip shark under the updated scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

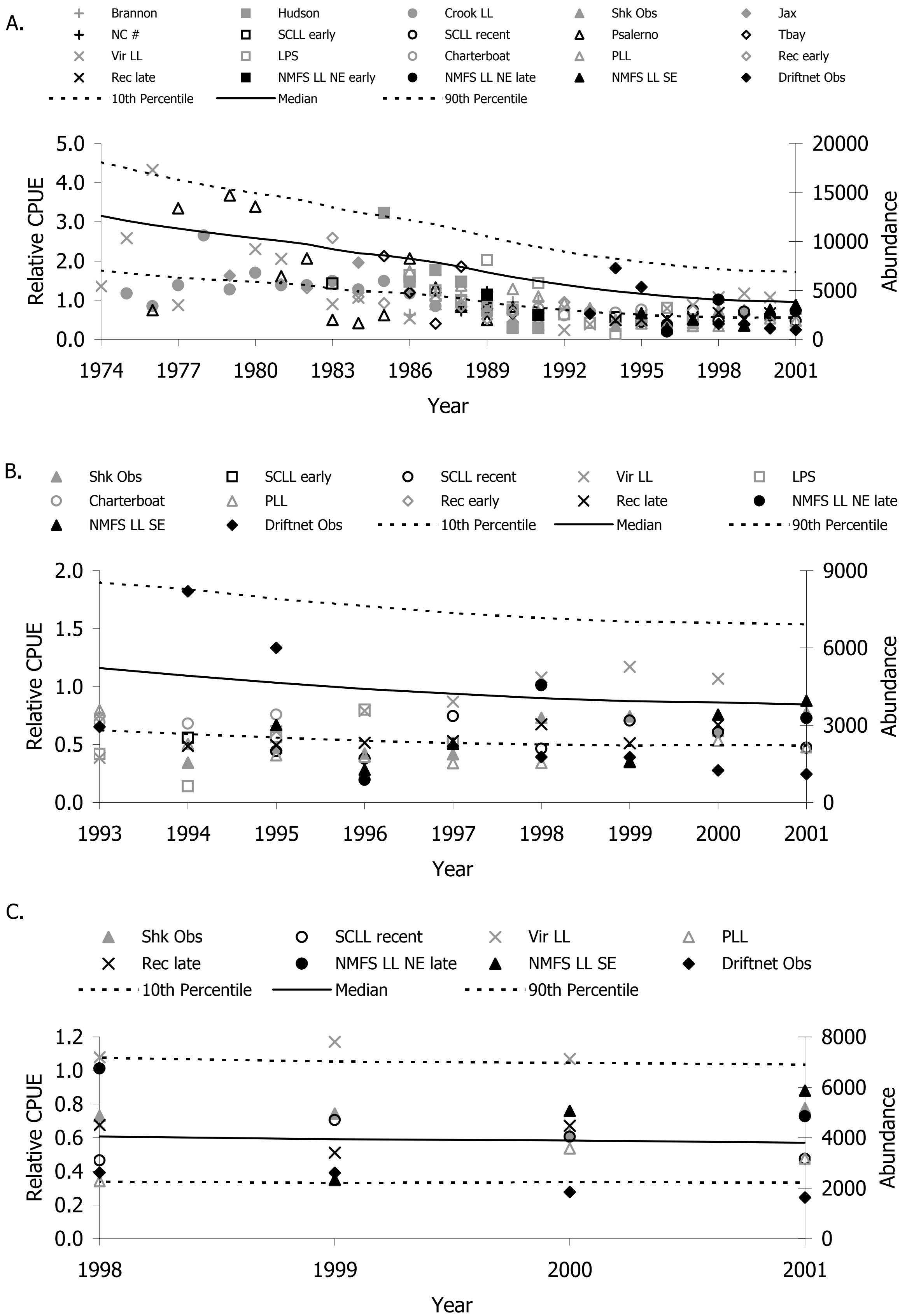


Figure 18. Abundance of the large coastal shark complex predicted by the surplus production model fitted to the catch and CPUE series for the baseline scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

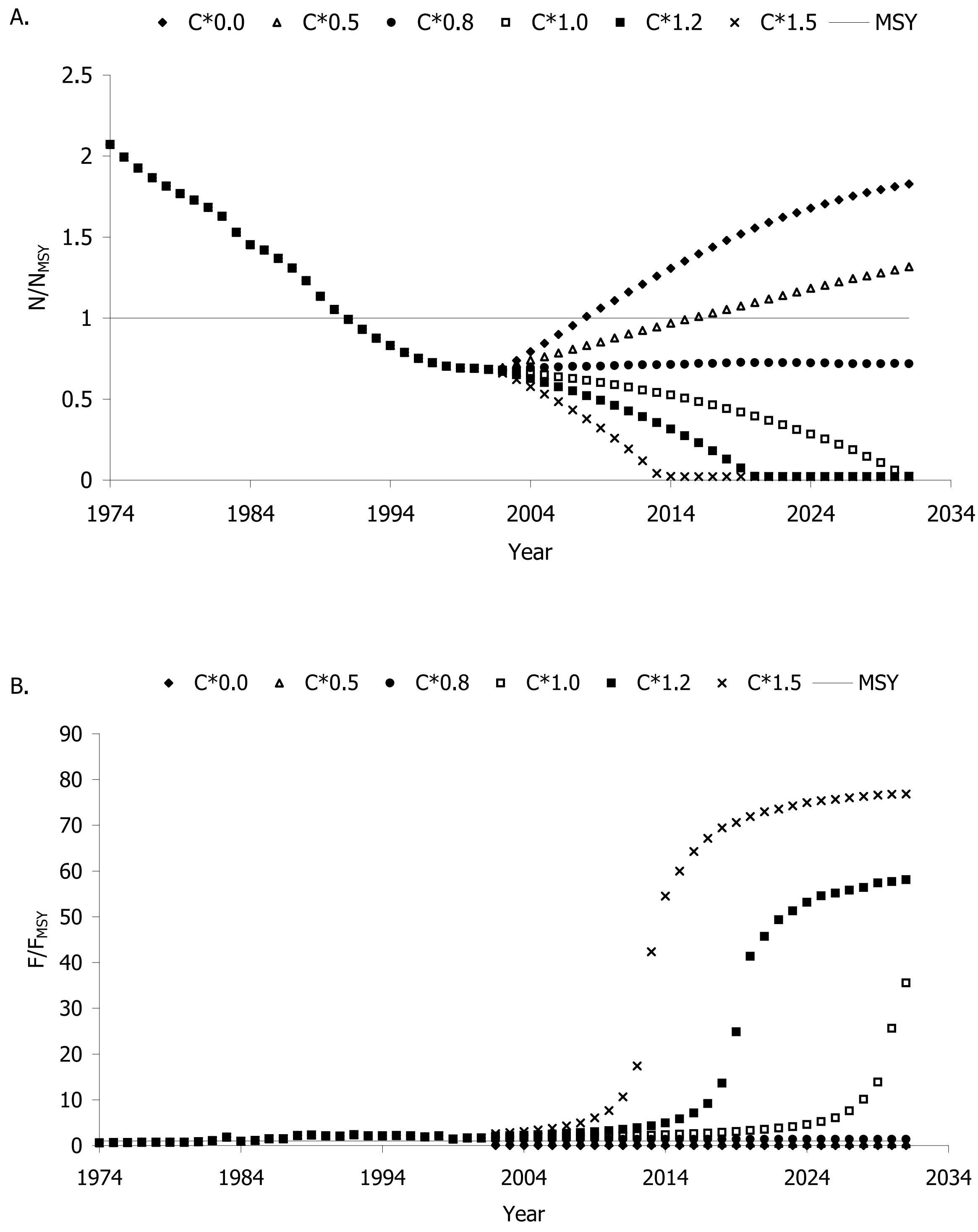


Figure 19. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the large coastal shark complex under the baseline scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

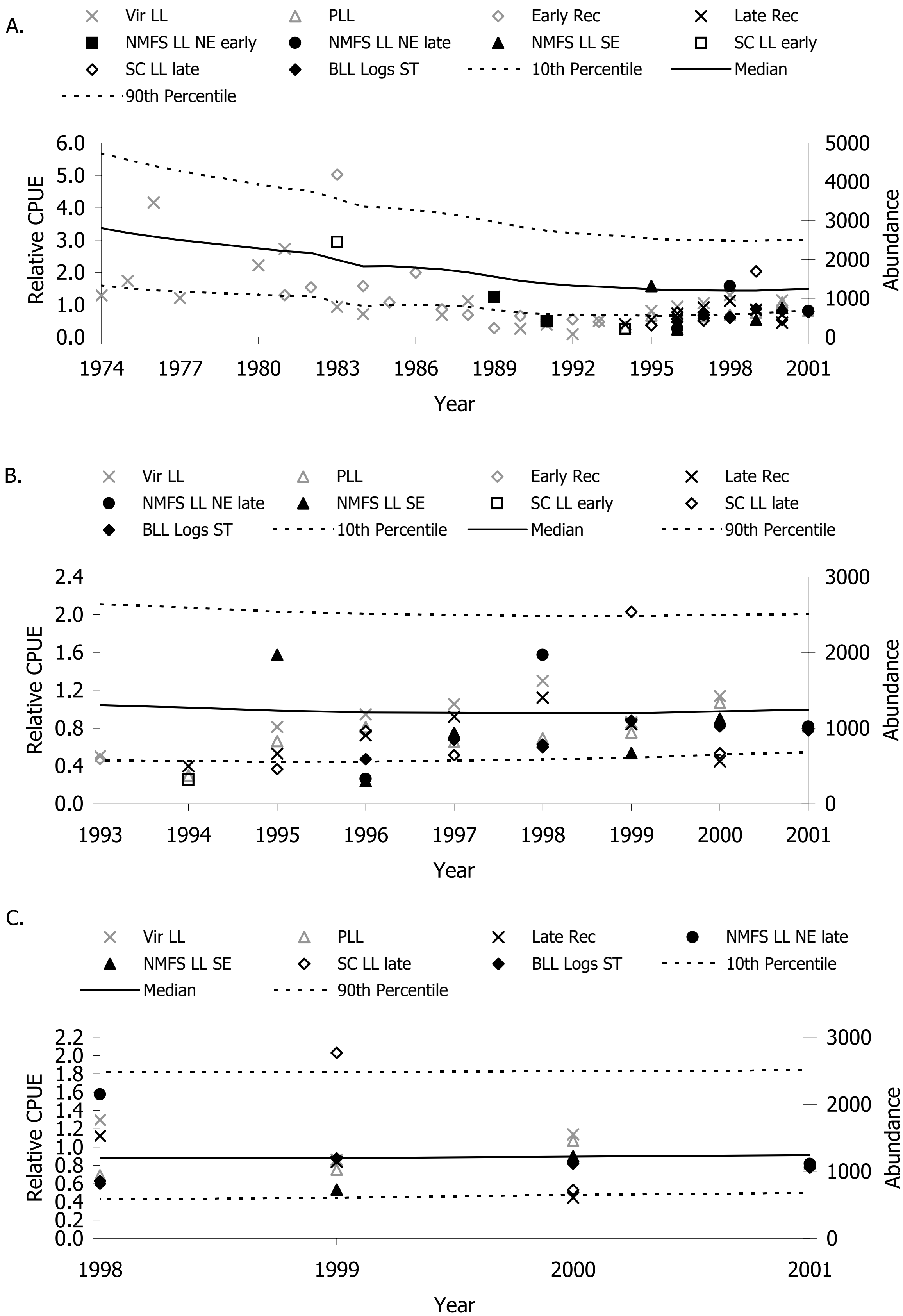


Figure 20. Abundance of the sandbar shark predicted by the surplus production model fitted to the catch and CPUE series for the baseline scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

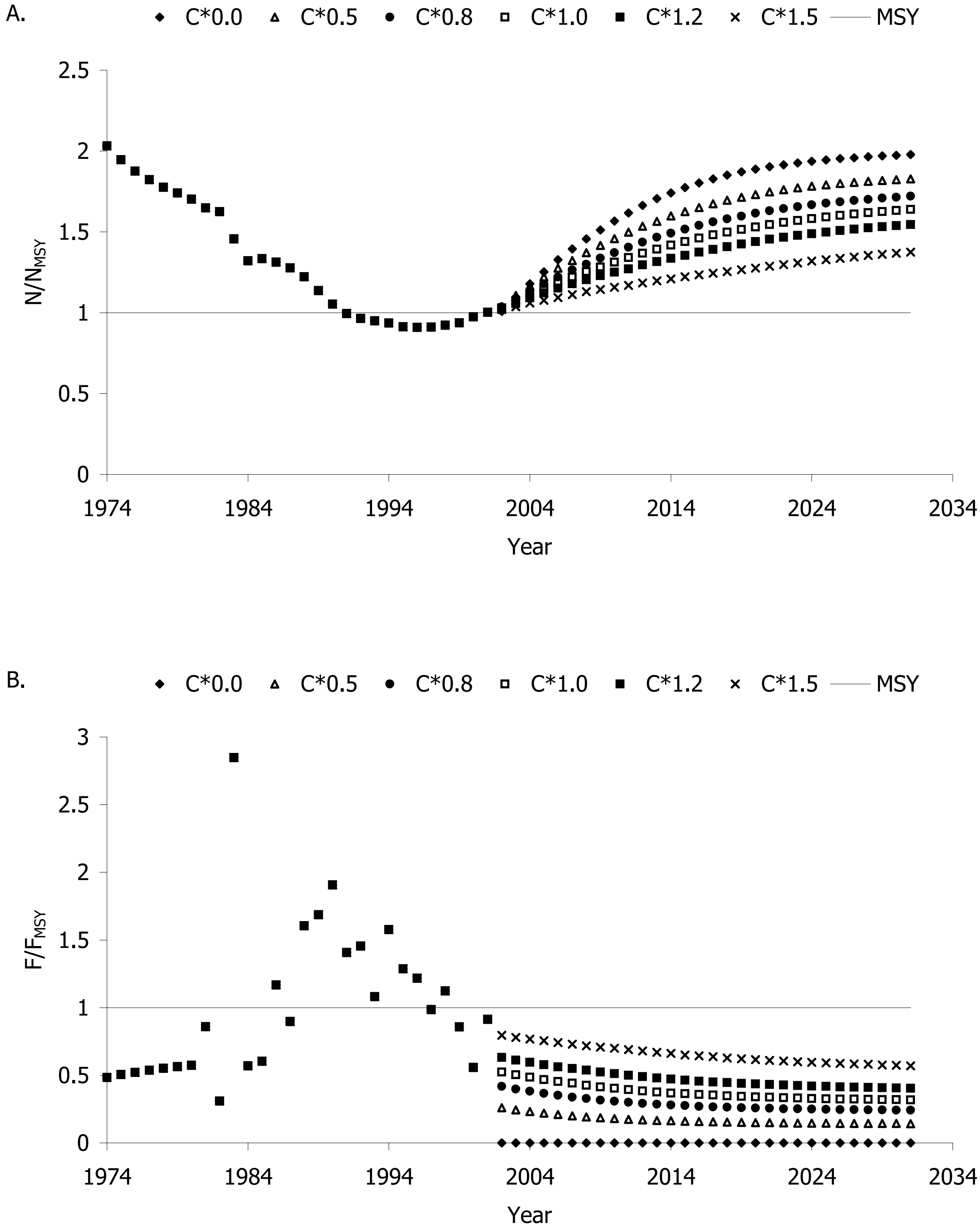


Figure 21. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the sandbar shark under the baseline scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

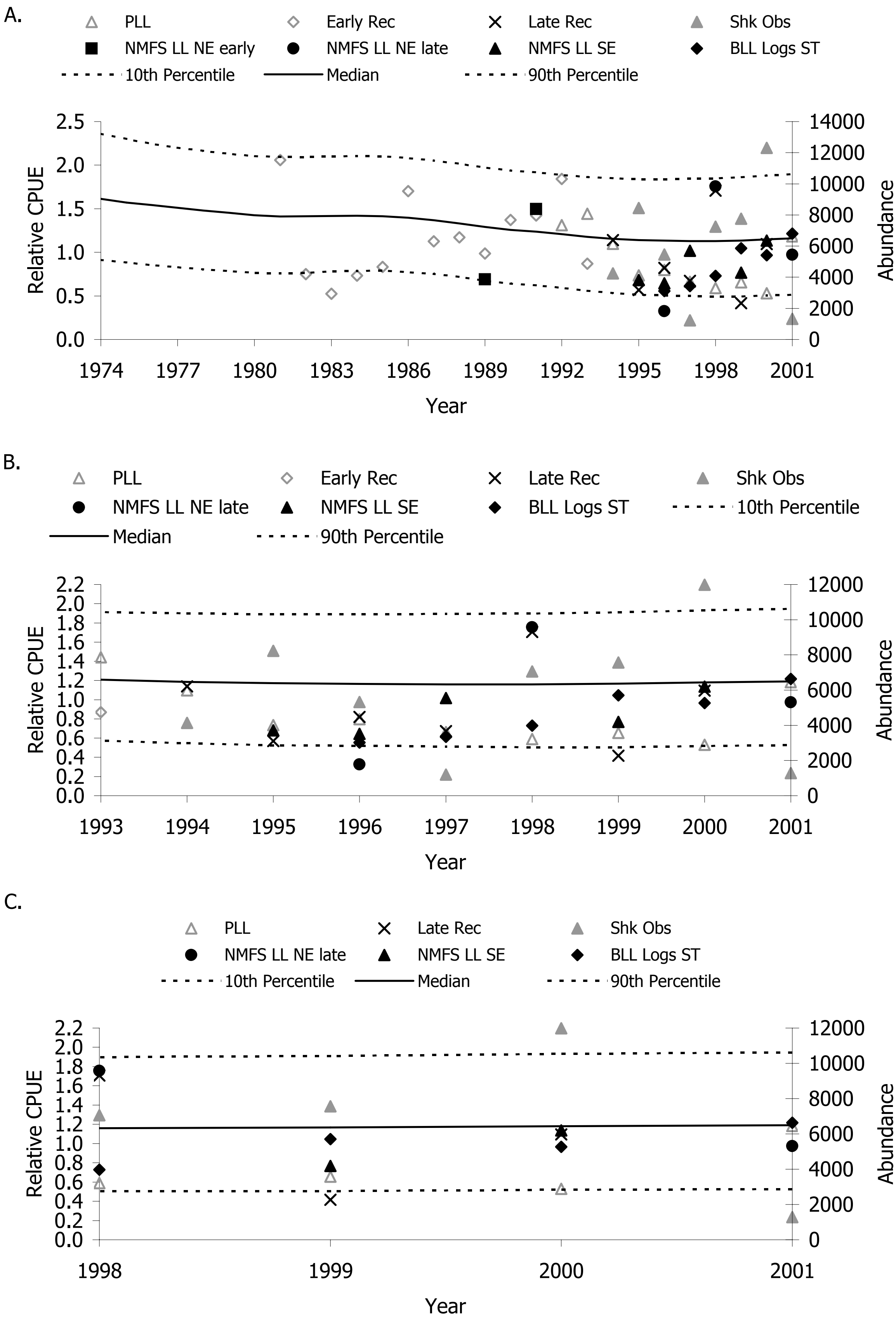


Figure 22. Abundance of the blacktip shark predicted by the surplus production model fitted to the catch and CPUE series for the baseline scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

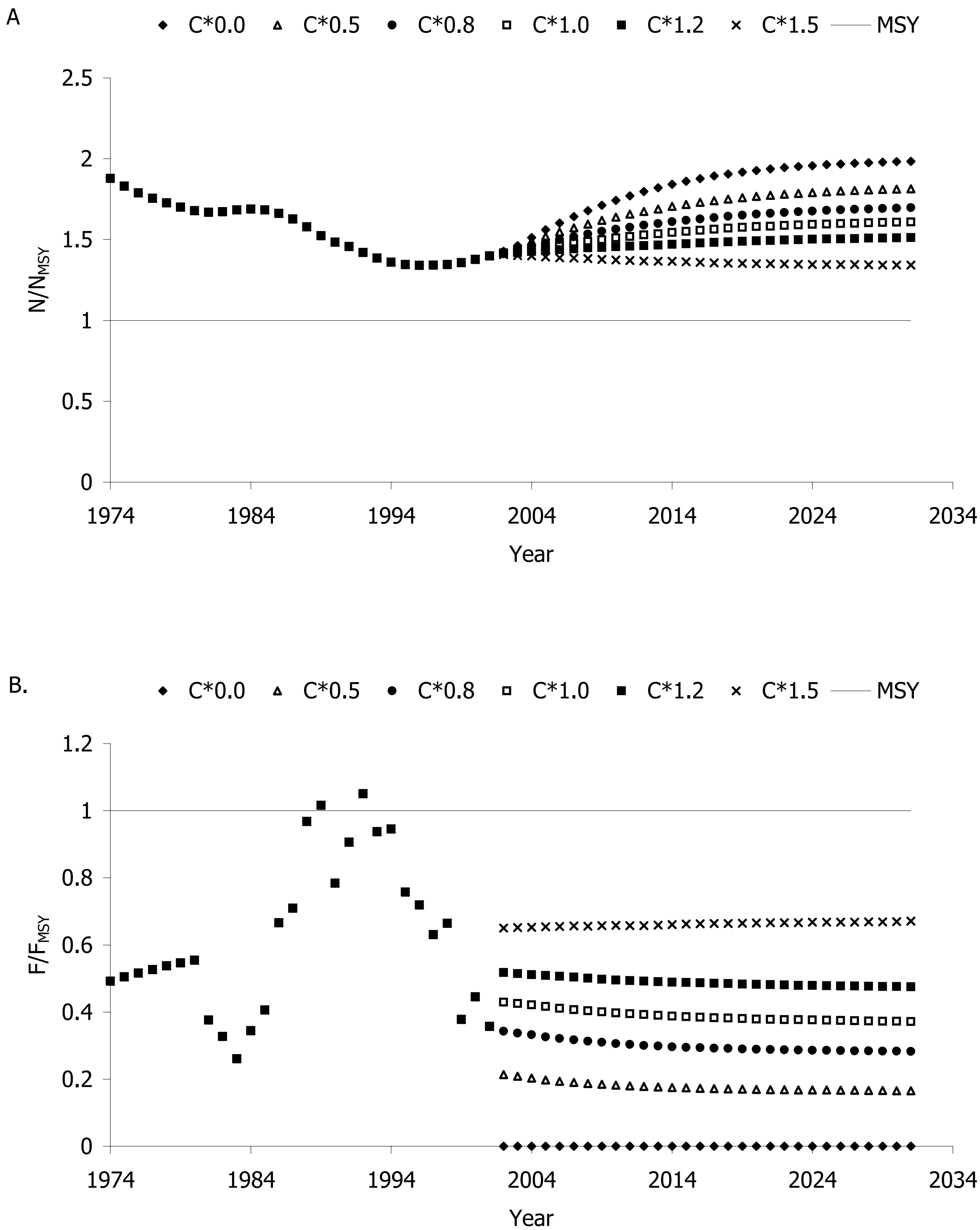


Figure 23. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the blacktip shark under the baseline scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

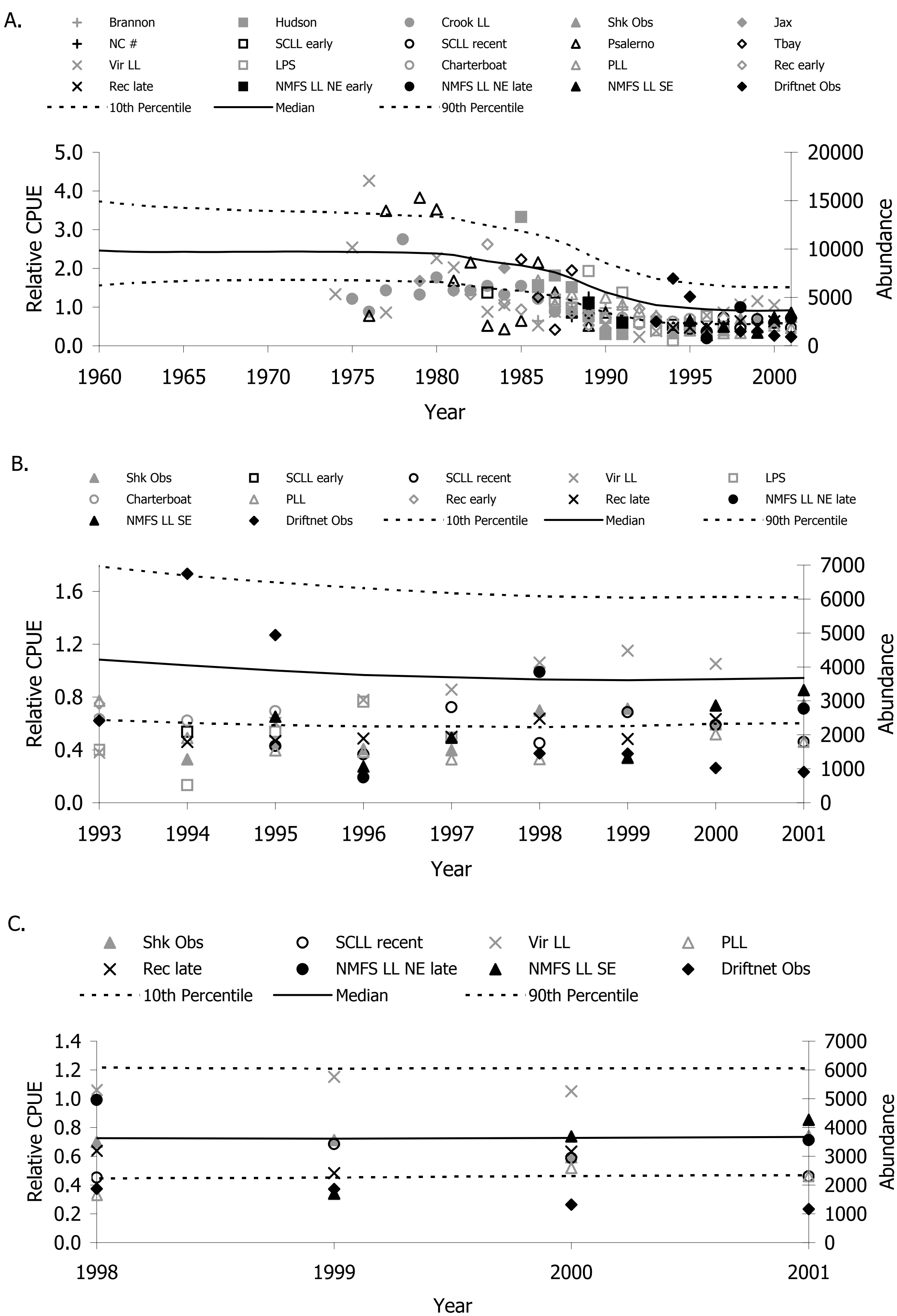


Figure 24. Abundance of the large coastal shark complex predicted by the surplus production model fitted to the catch and CPUE series for the alternative catch scenario. The series are scaled (divided by the catchability coefficient for each series and the overall mean for all series). A) 1974-2001, B) 1993-2001, C) 1998-2001.

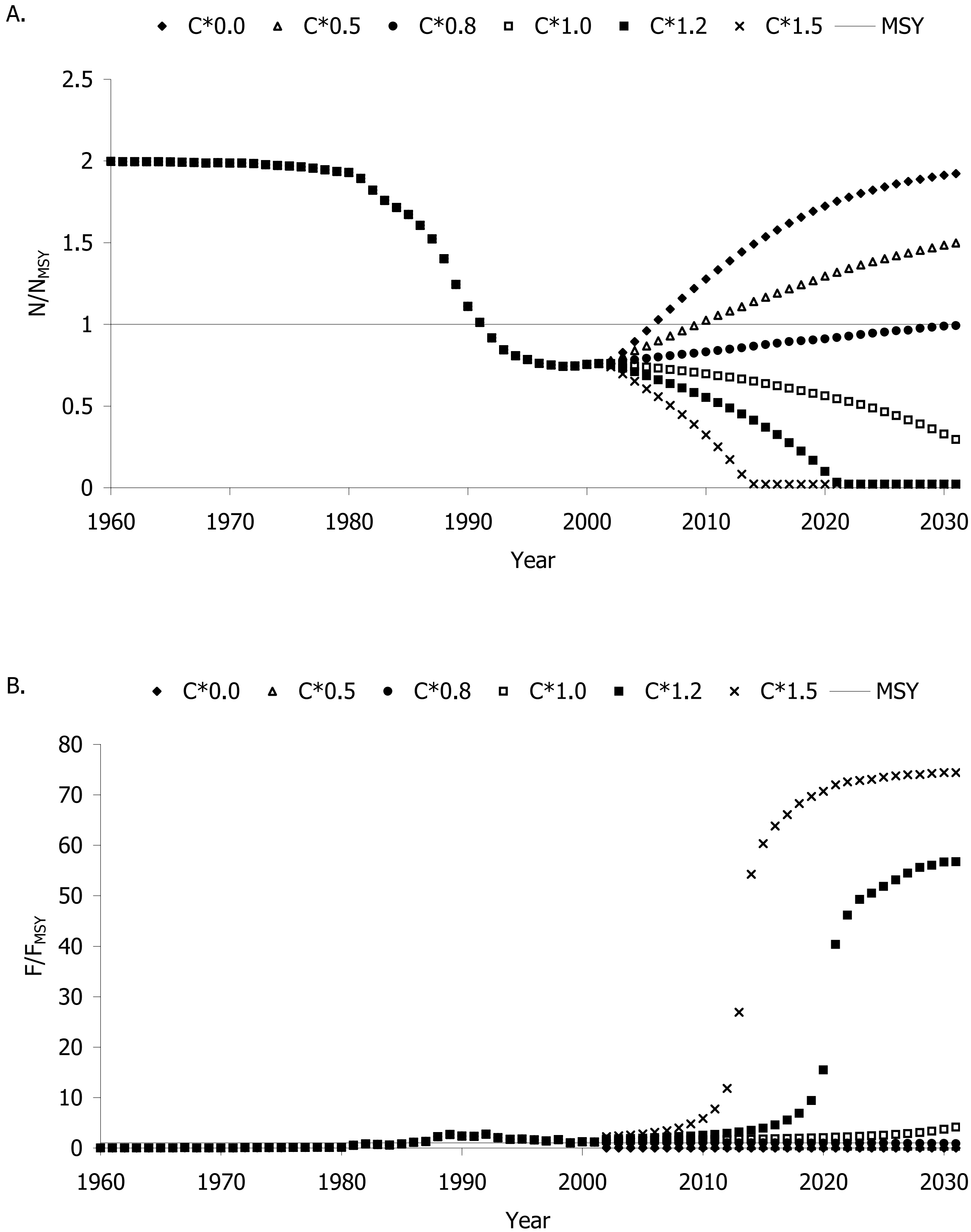


Figure 25. Estimated relative abundance (A) and fishing mortality rate (B) trajectories and projections (from 2001 to 2031) for alternative total allowable catch (TAC) harvesting policies (0 catch, 50%, 80%, 100%, 120%, and 150% of the 2000 catch) for the large coastal shark complex under the alternative catch scenario. Values shown are medians; the horizontal line at 1 denotes the MSY (MSC) level.

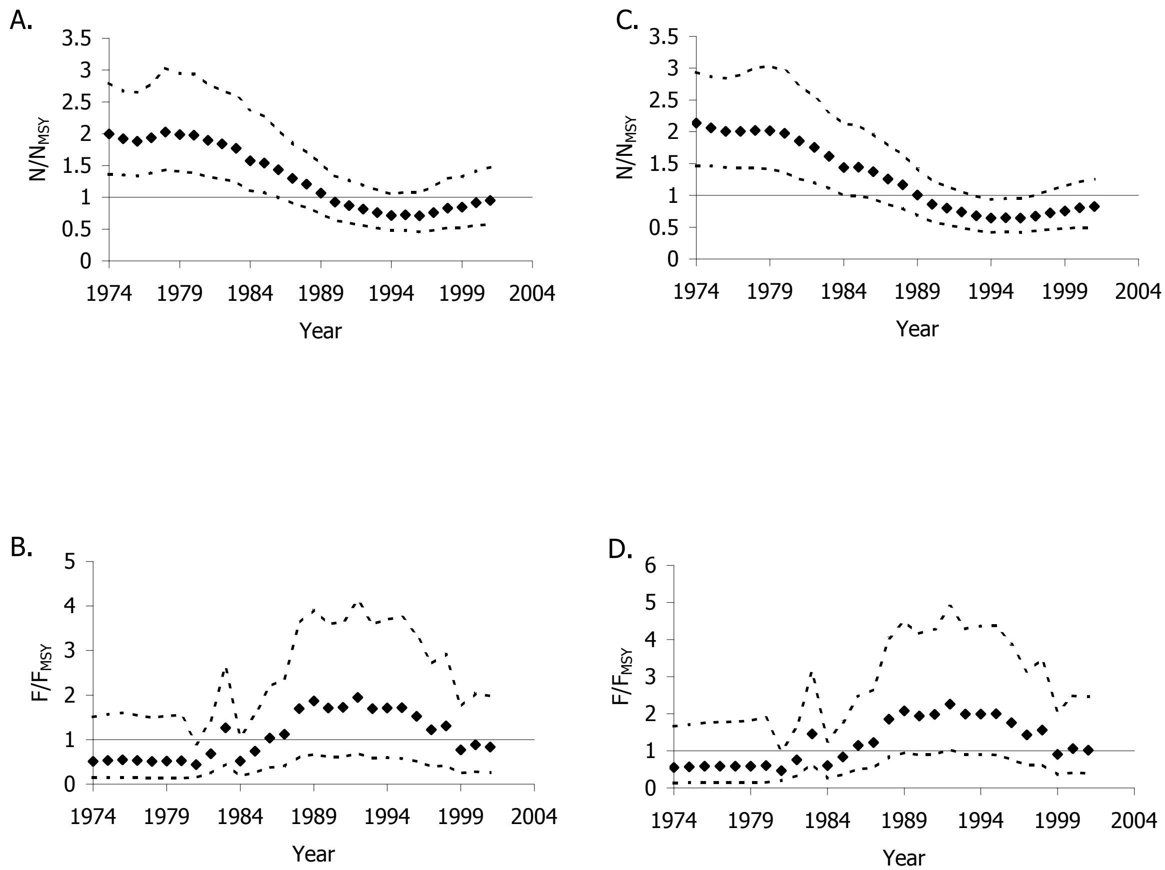


Figure 26. Estimated relative abundance (A and C) and fishing mortality rate (B and D) trajectories for the large coastal shark complex under the updated scenario using the state-space surplus production model (SSSPM) in winBUGS. The panels on the left side correspond to the form of the model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

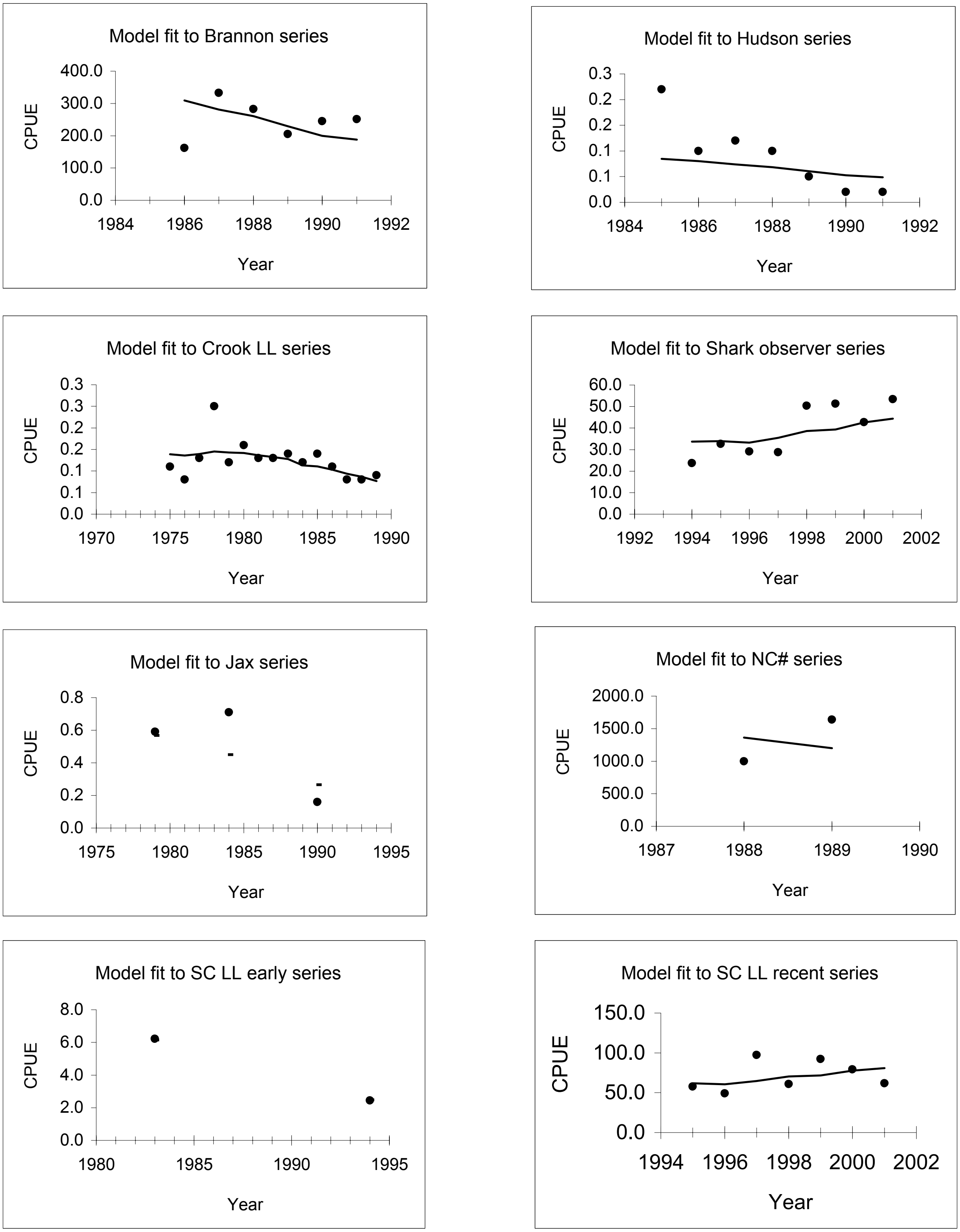


Figure 27. WinBUGS SSSPM fits to the individual CPUE series of the updated scenario for the large coastal shark complex.

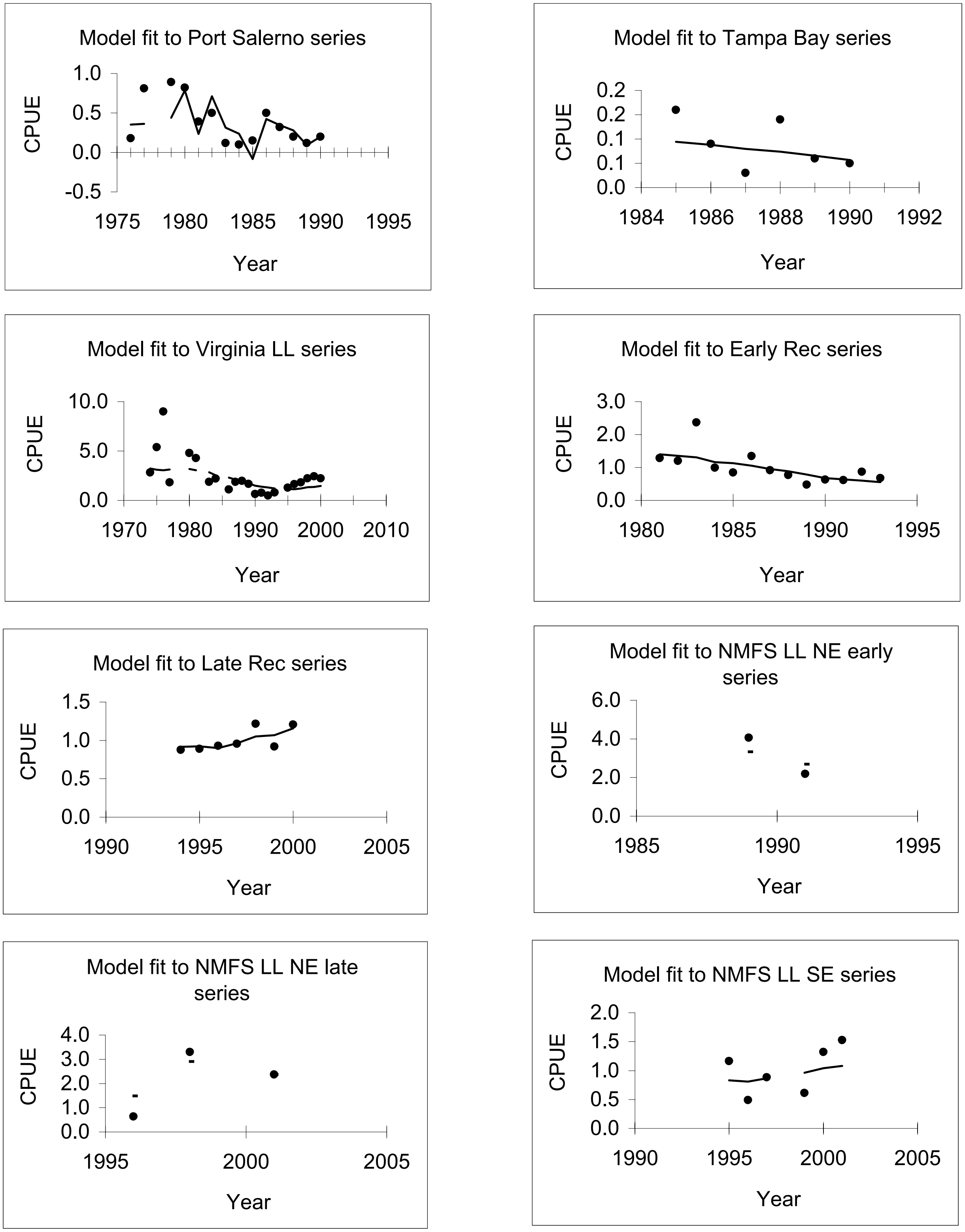


Figure 27 (continued). WinBUGS SSSPM fits to the individual CPUE series of the updated scenario for the large coastal shark complex.

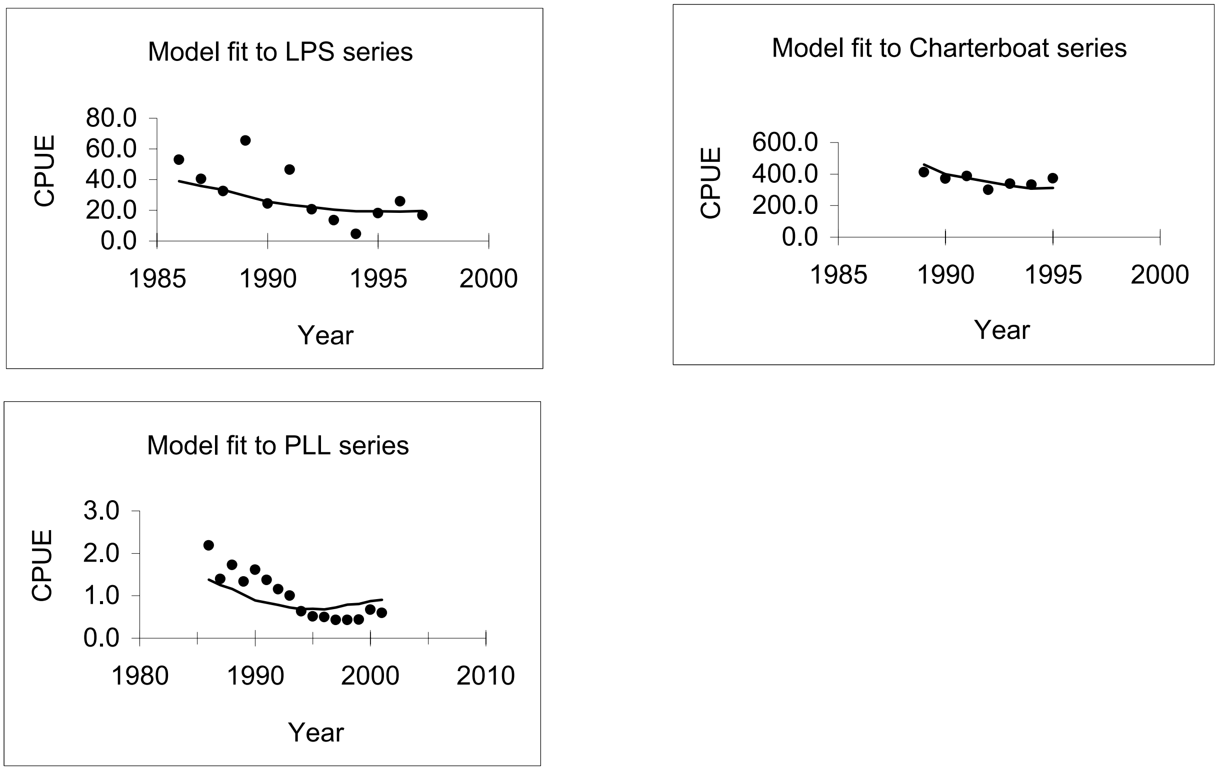


Figure 27 (continued). WinBUGS SSSPM fits to the individual CPUE series of the updated scenario for the large coastal shark complex.

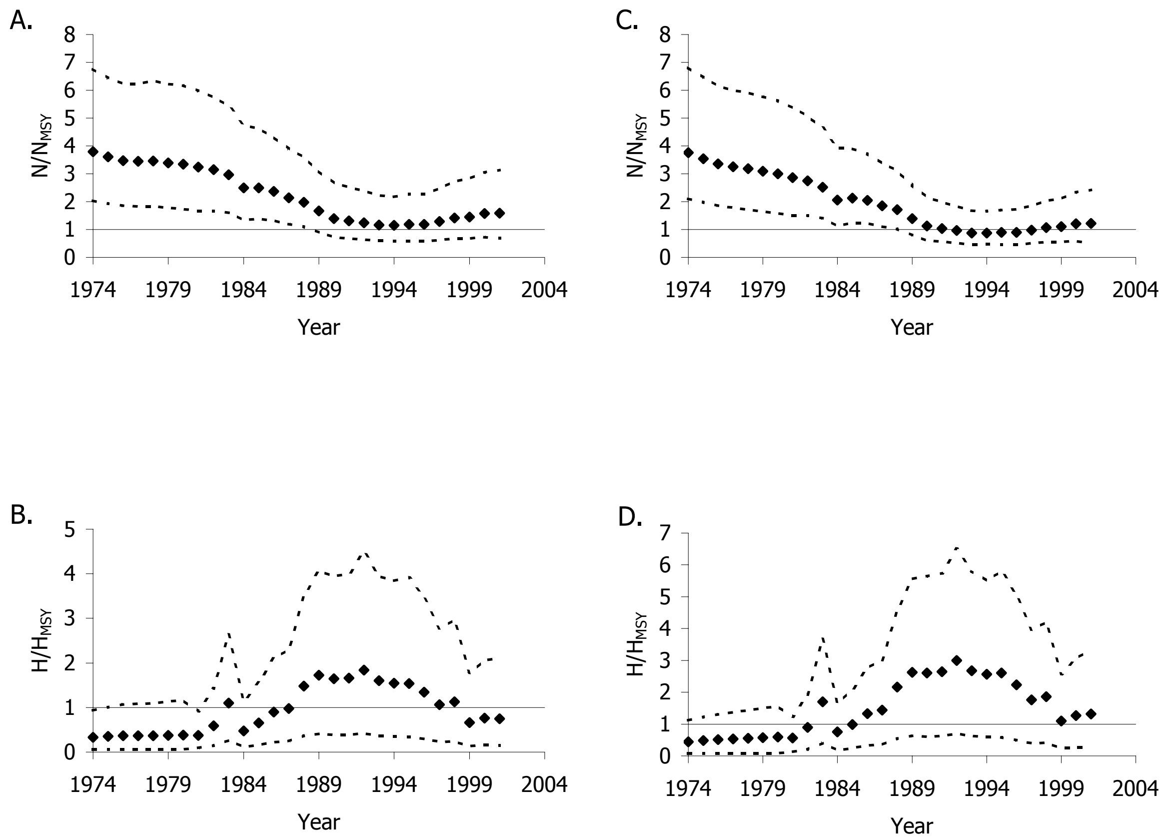


Figure 28. Estimated relative abundance (A and C) and harvest rate (B and D) trajectories for the large coastal shark complex under the updated scenario using the state-space lagged recruitment, survival, and growth model (SSLRSG) in winBUGS. The panels on the left side correspond to the form of the model model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

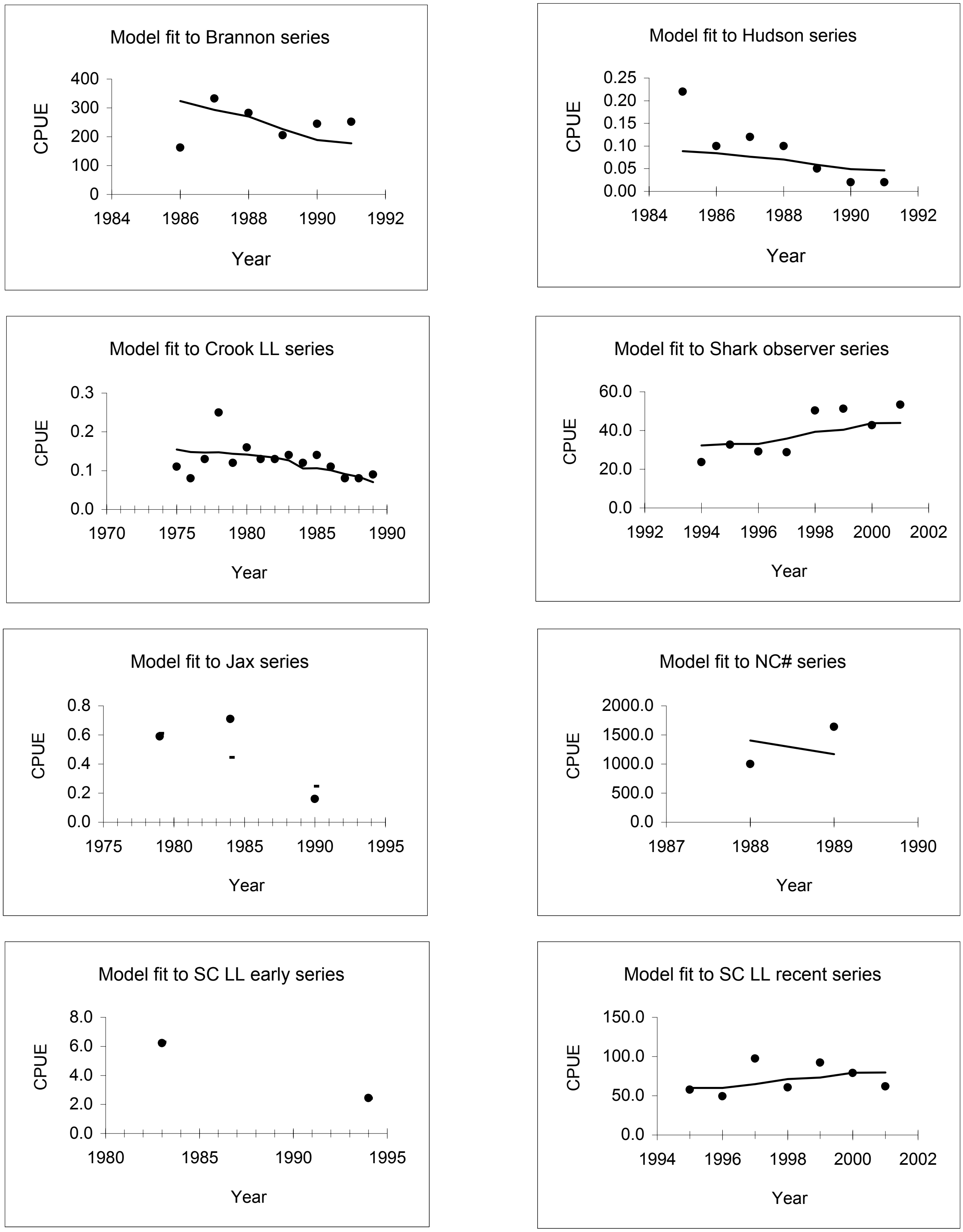


Figure 29. WinBUGS SSLRSG model fits to the individual CPUE series of the updated scenario for the large coastal shark complex.

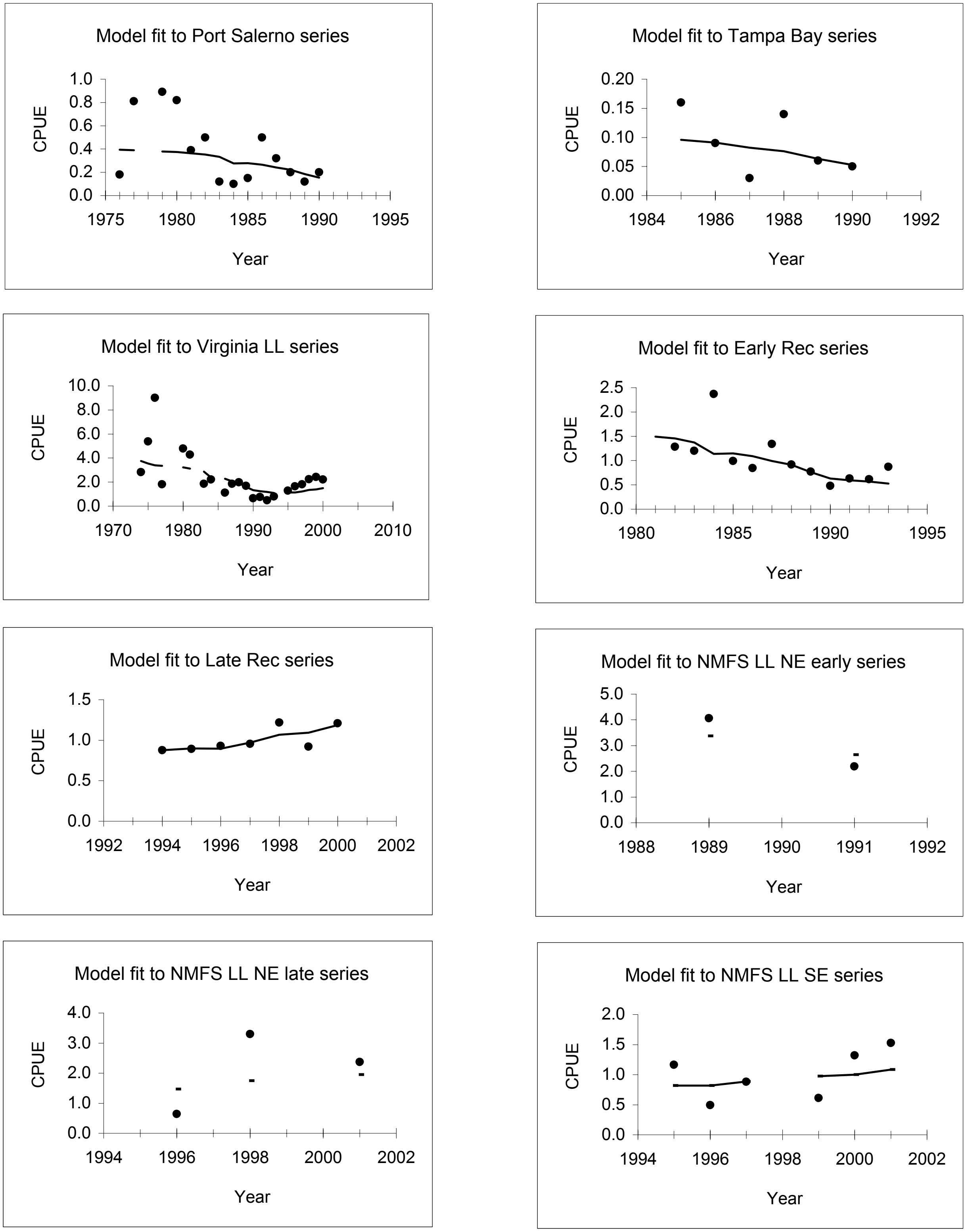
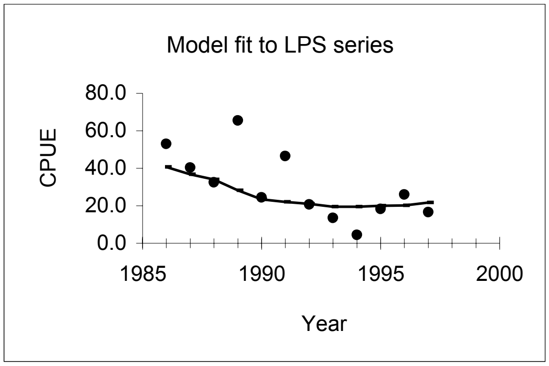
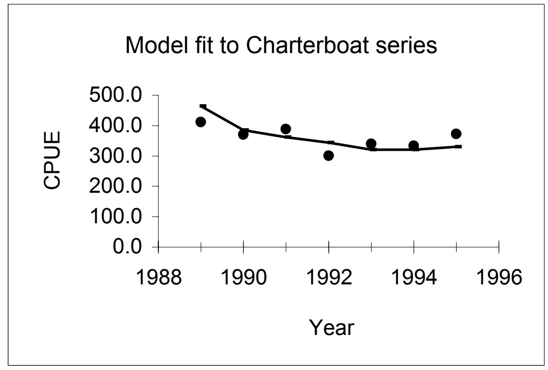


Figure 29 (continued). WinBUGS SSLRSG model fits to the individual CPUE series of the updated scenario for the large coastal shark complex.





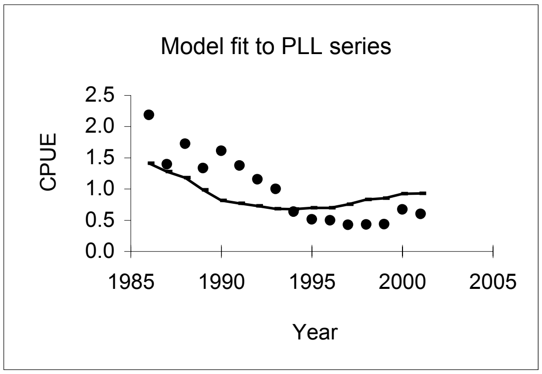


Figure 29 (continued). WinBUGS SSLRSG model fits to the individual CPUE series of the updated scenario for the large coastal shark complex.

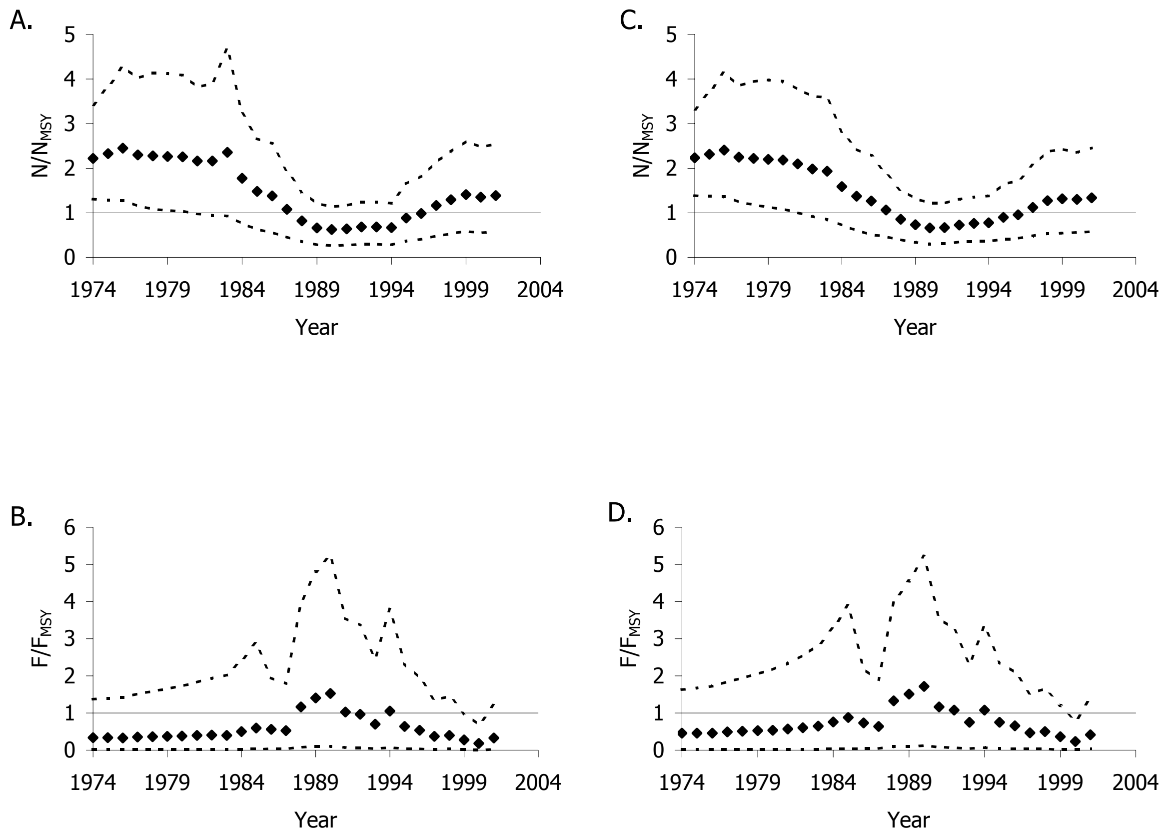


Figure 30. Estimated relative abundance (A and C) and fishing mortality rate (B and D) trajectories for the sandbar shark under the updated scenario using the state-space surplus production model (SSSPM) in winBUGS. The panels on the left side correspond to the form of the model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

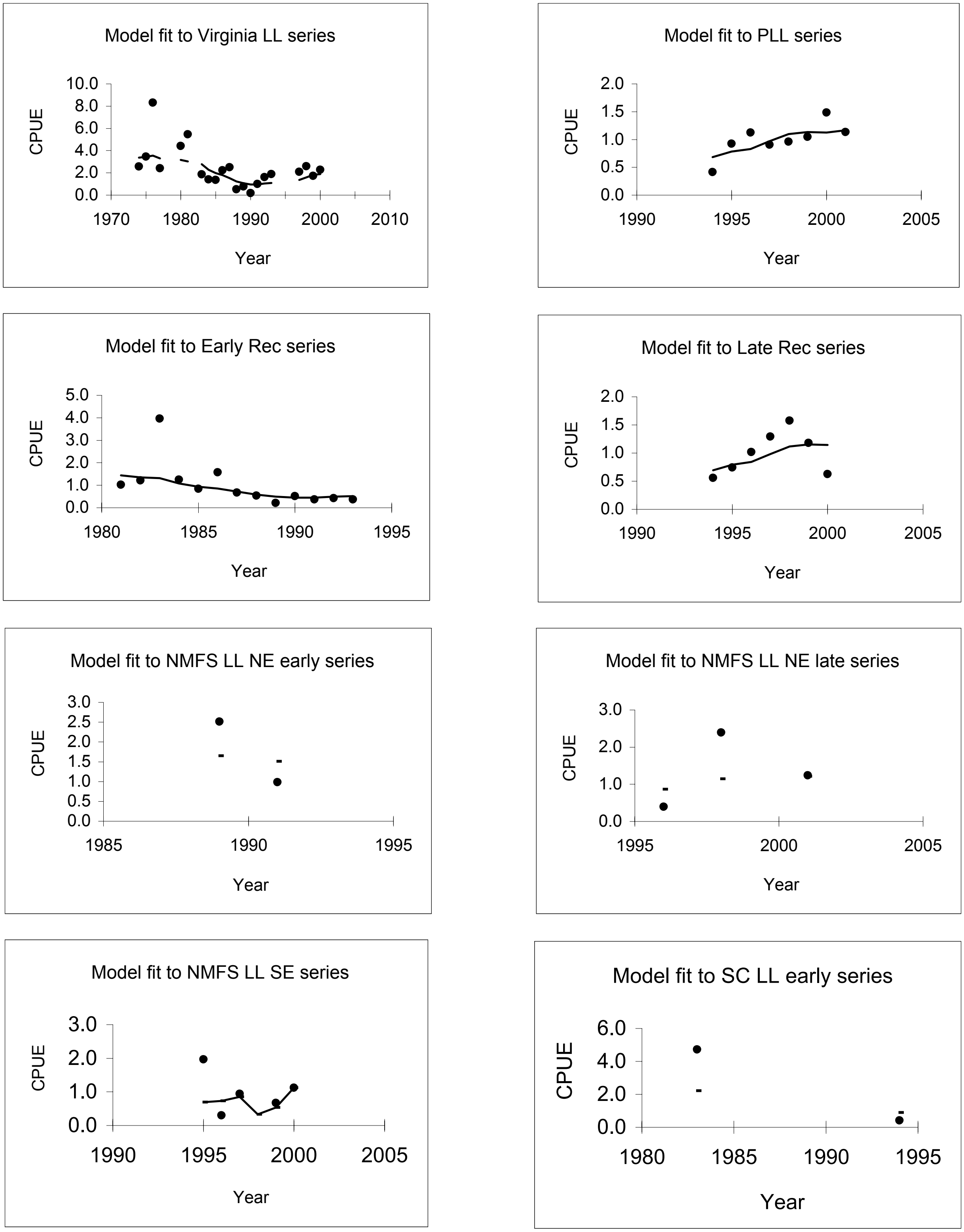
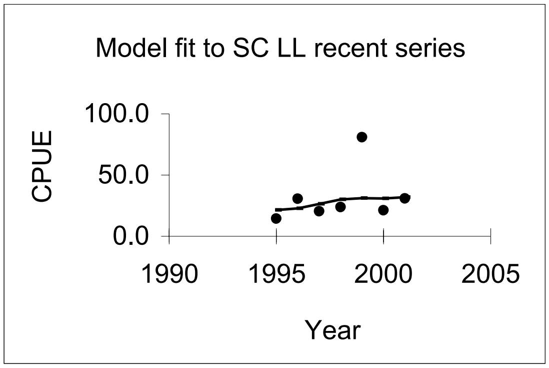


Figure 31. WinBUGS SSSPM fits to the individual CPUE series of the updated scenario for sandbar shark.



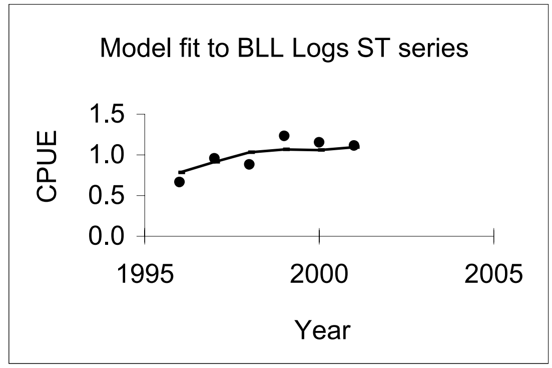


Figure 31 (continued). WinBUGS SSSPM fits to the individual CPUE series of the updated scenario for sandbar shark.

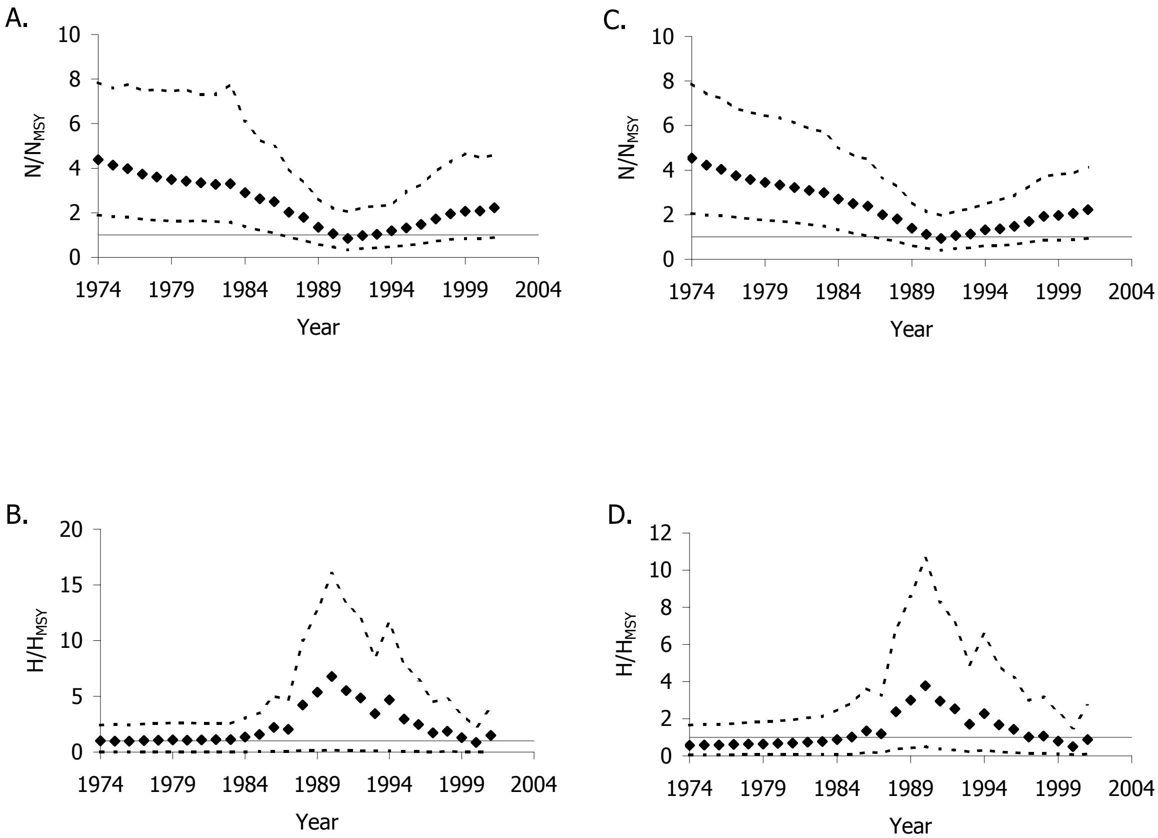


Figure 32. Estimated relative abundance (A and C) and harvest rate (B and D) trajectories for the sandbar shark under the updated scenario using the state-space lagged recruitment, survival, and growth model (SSLRSG) in winBUGS. The panels on the left side correspond to the form of the model model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

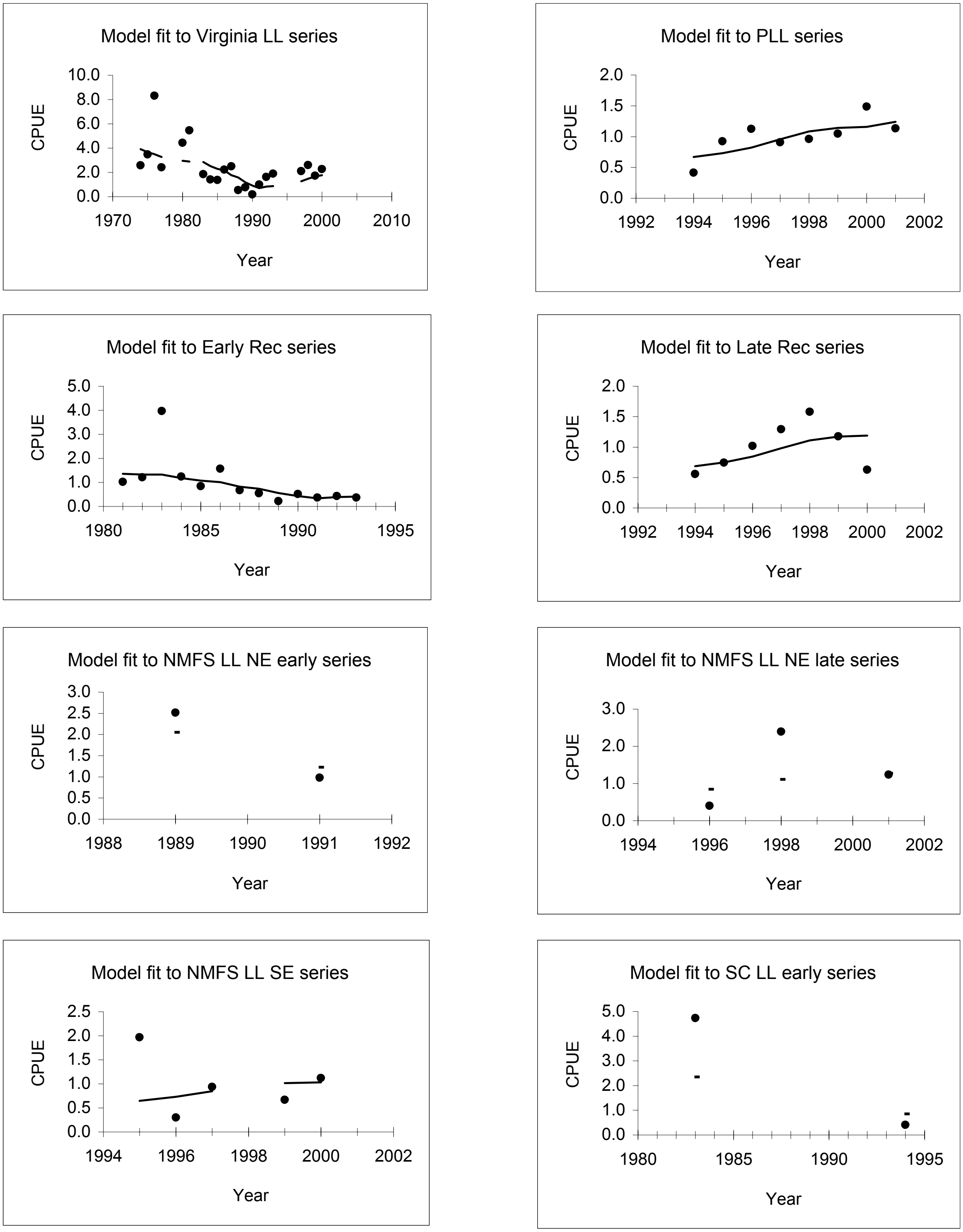
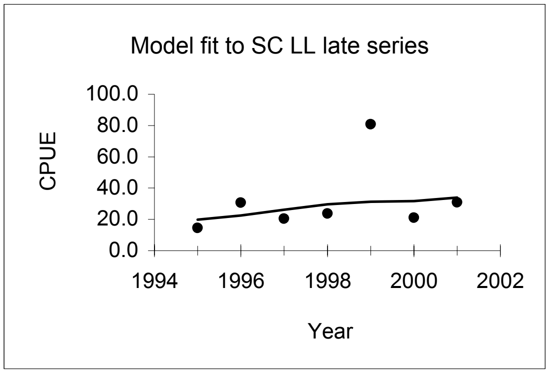


Figure 33. WinBUGS SSLRSG model fits to the individual CPUE series of the updated scenario for sandbar shark.



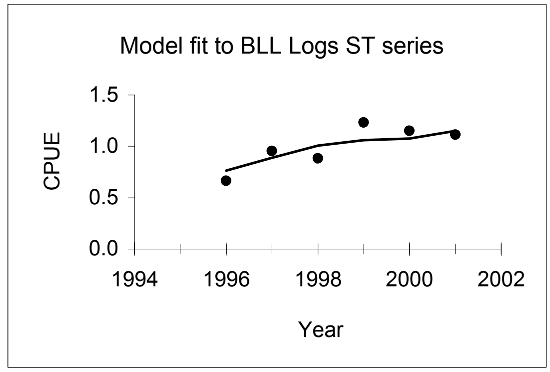


Figure 33 (continued). WinBUGS SSLRSG model fits to the individual CPUE series of the updated scenario for sandbar shark.

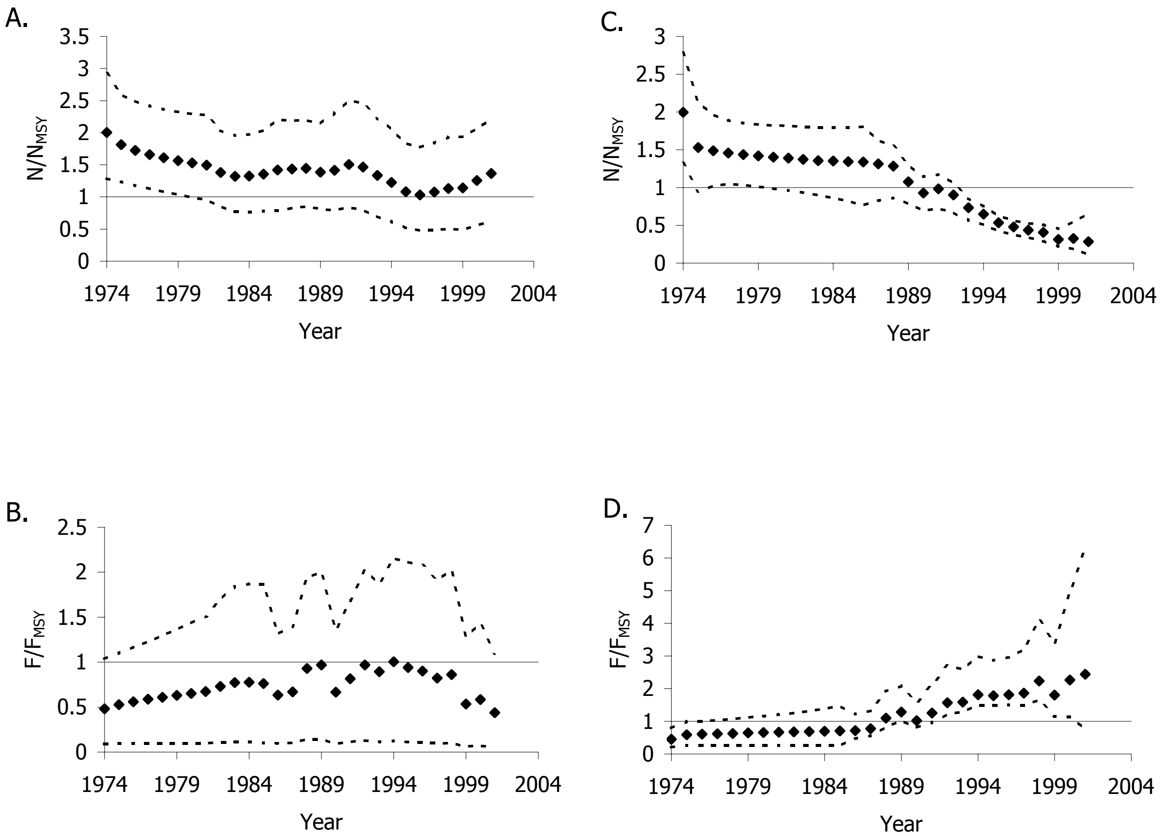


Figure 34. Estimated relative abundance (A and C) and fishing mortality rate (B and D) trajectories for the blacktip shark under the updated scenario using the state-space surplus production model (SSSPM) in winBUGS. The panels on the left side correspond to the form of the model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

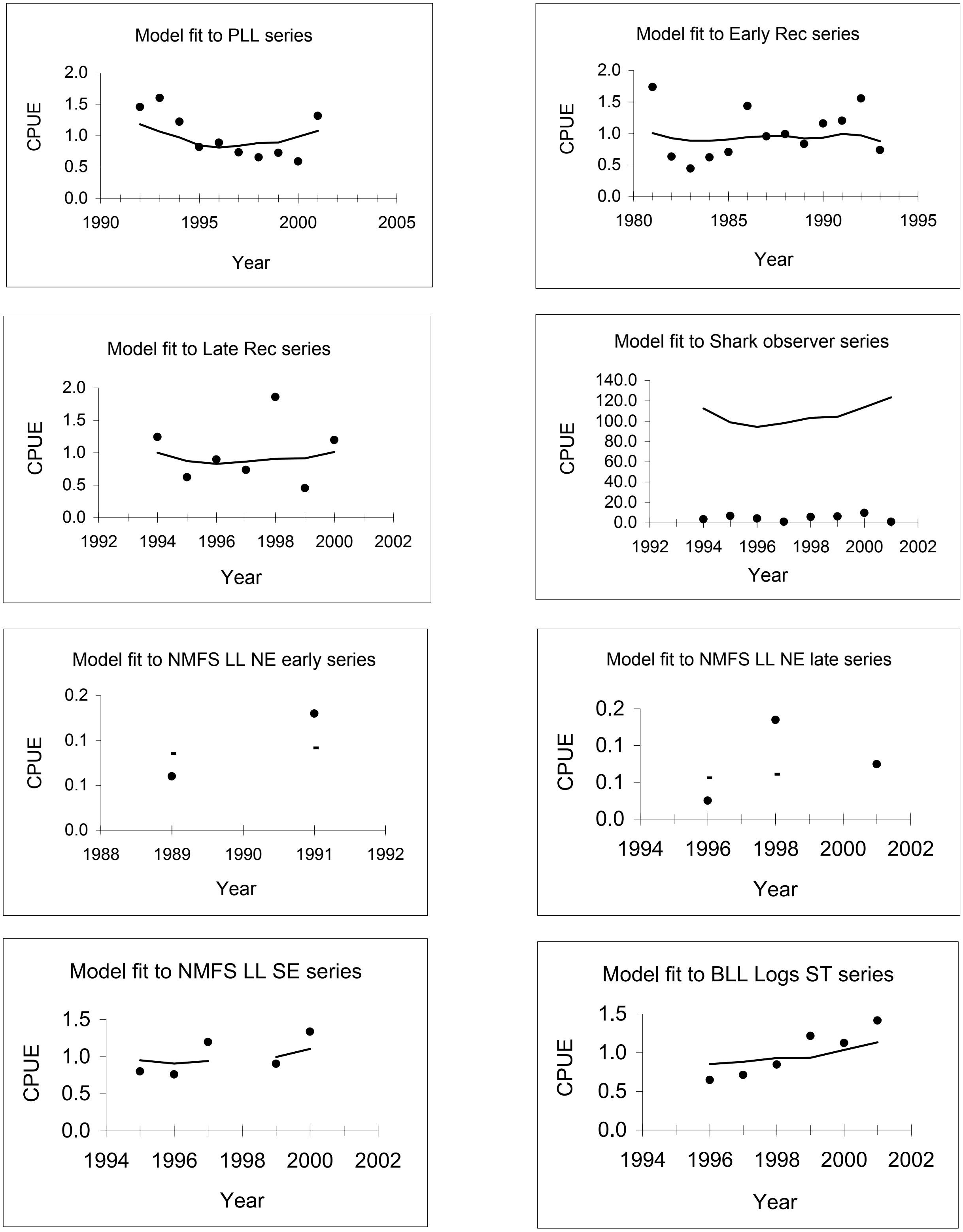


Figure 35. WinBUGS SSSPM fits to the individual CPUE series of the updated scenario for blacktip shark.

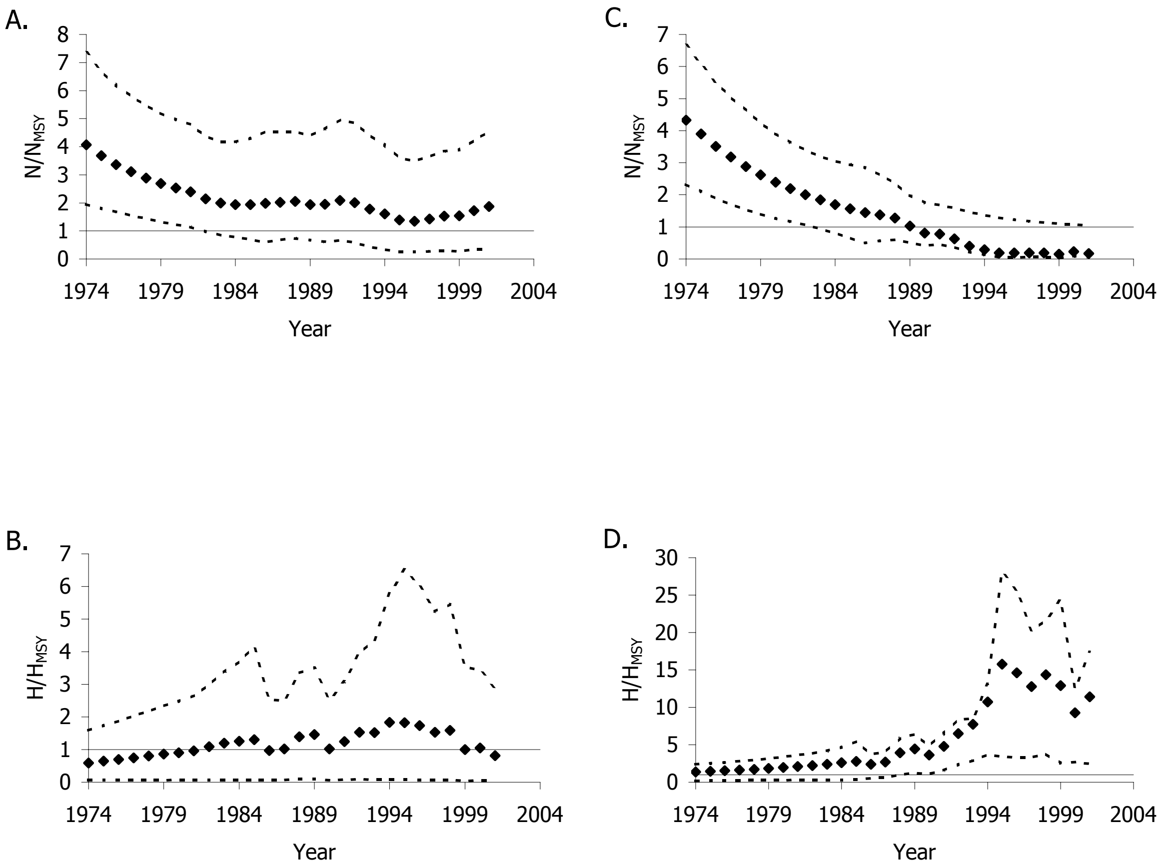


Figure 36. Estimated relative abundance (A and C) and harvest rate (B and D) trajectories for the blacktip shark under the updated scenario using the state-space lagged recruitment, survival, and growth model (SSLRSG) in winBUGS. The panels on the left side correspond to the form of the model model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

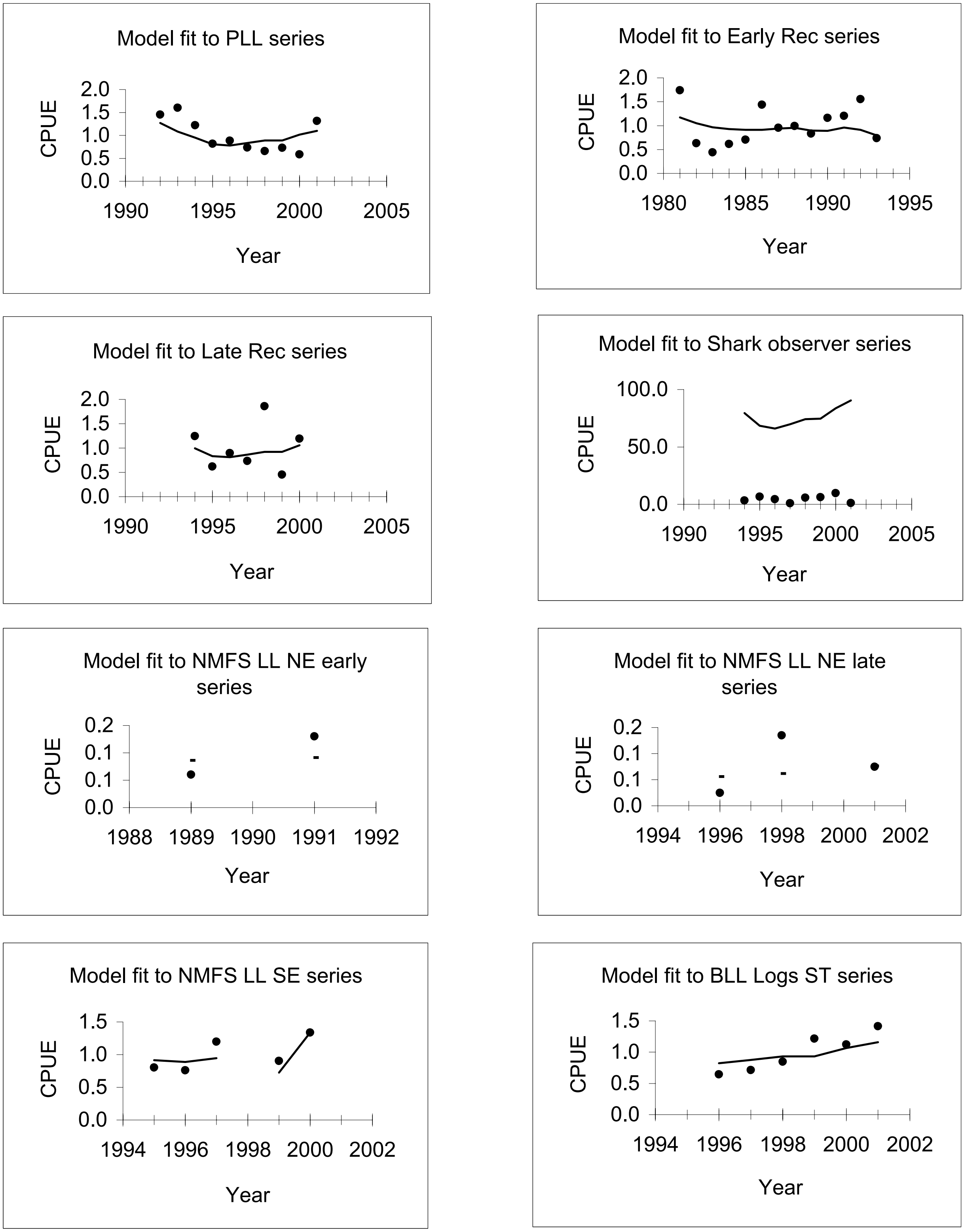


Figure 37. WinBUGS SSLRSG model fits to the individual CPUE series of the updated scenario for blacktip shark.

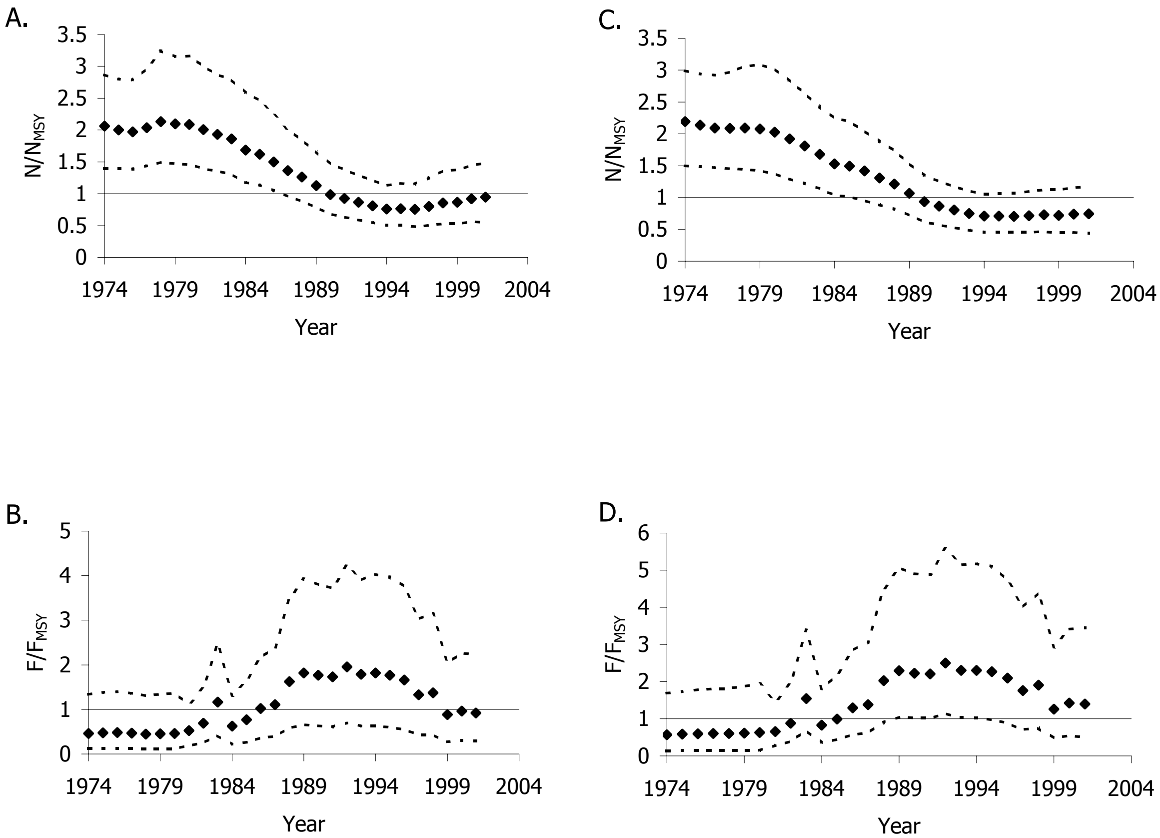


Figure 38. Estimated relative abundance (A and C) and fishing mortality rate (B and D) trajectories for the large coastal shark complex under the baseline scenario using the state-space surplus production model (SSSPM) in winBUGS. The panels on the left side correspond to the form of the model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

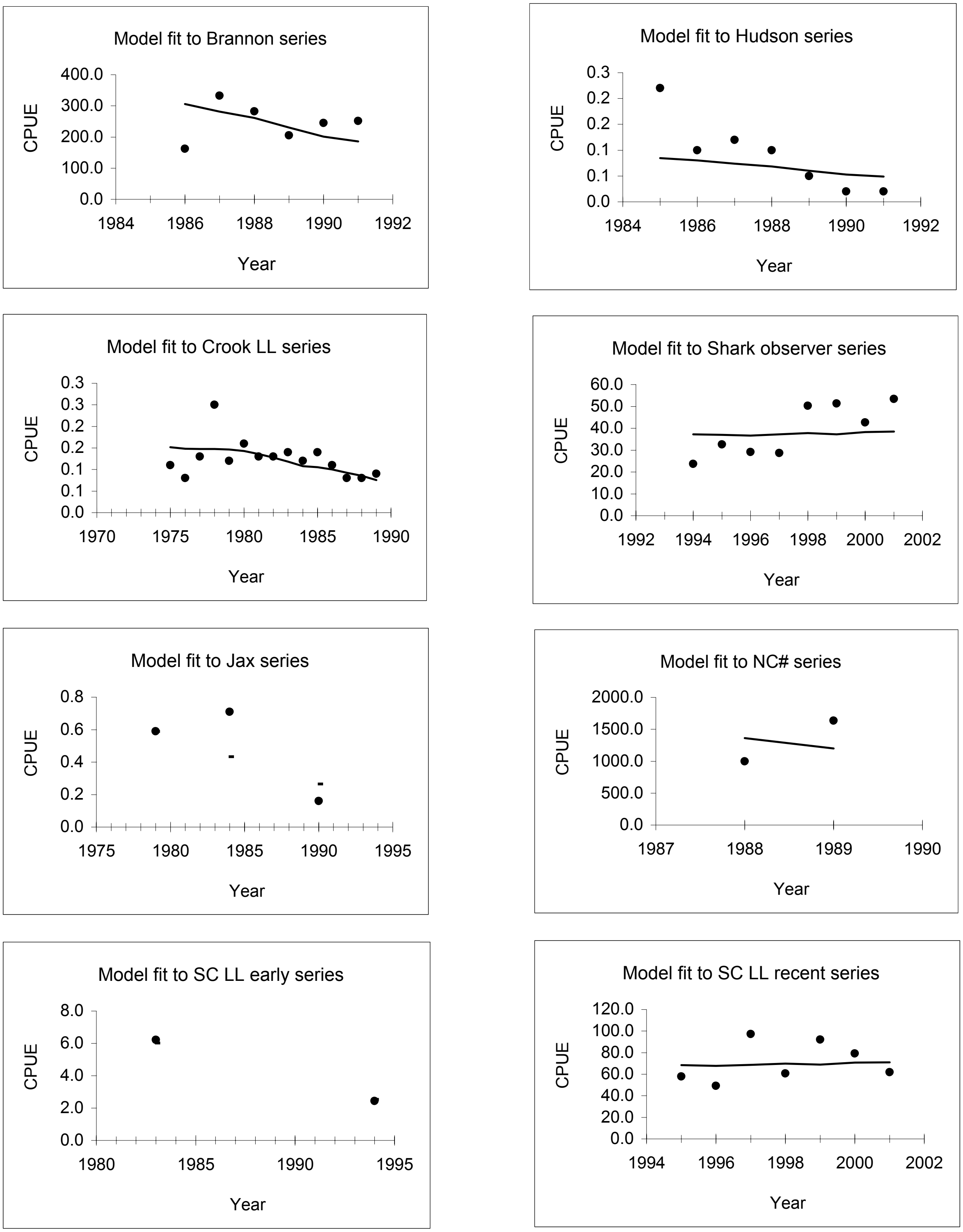


Figure 39. WinBUGS SSSPM fits to the individual CPUE series of the baseline scenario for the large coastal shark complex.

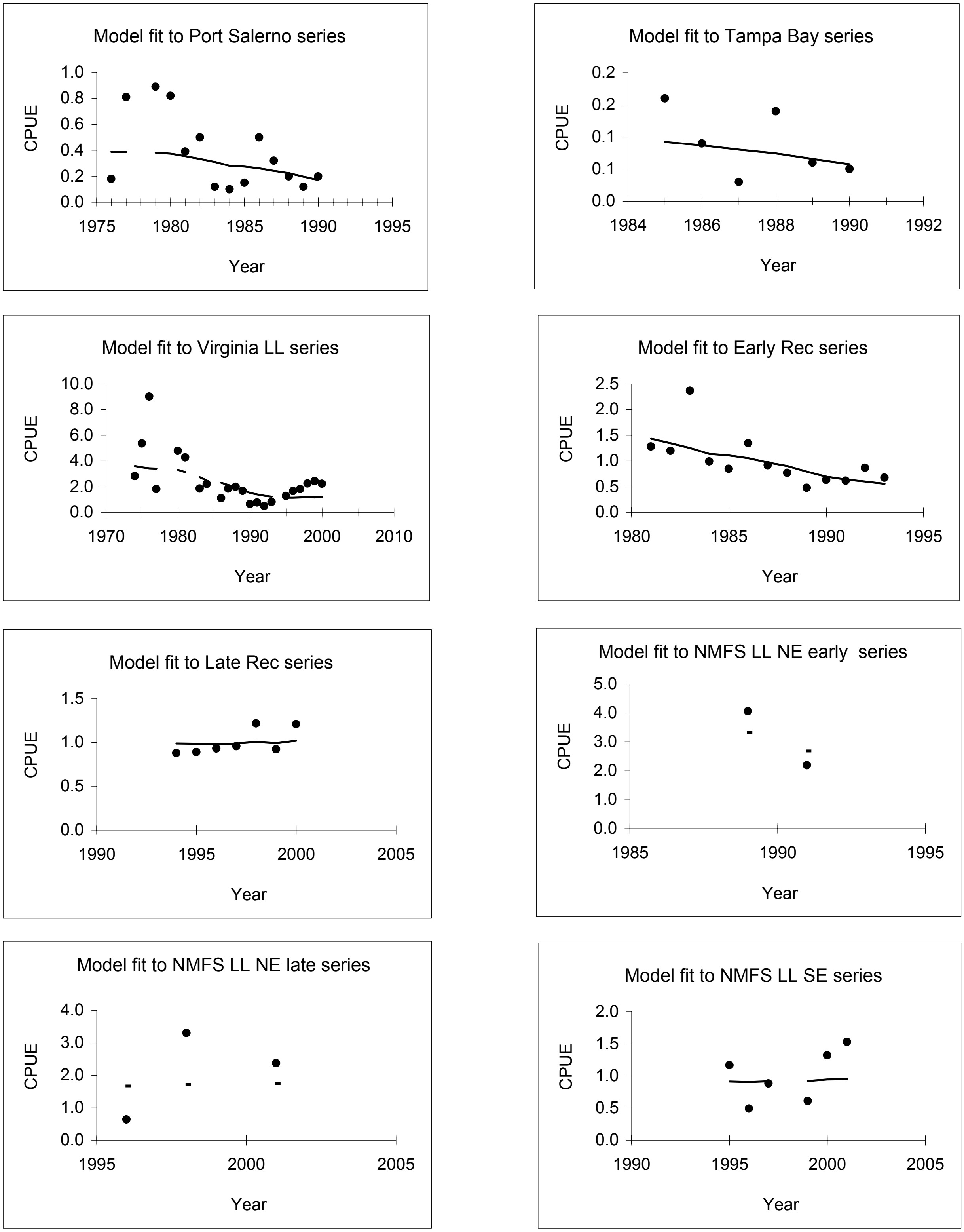


Figure 39 (continued). WinBUGS SSSPM fits to the individual CPUE series of the baseline scenario for the large coastal shark complex.

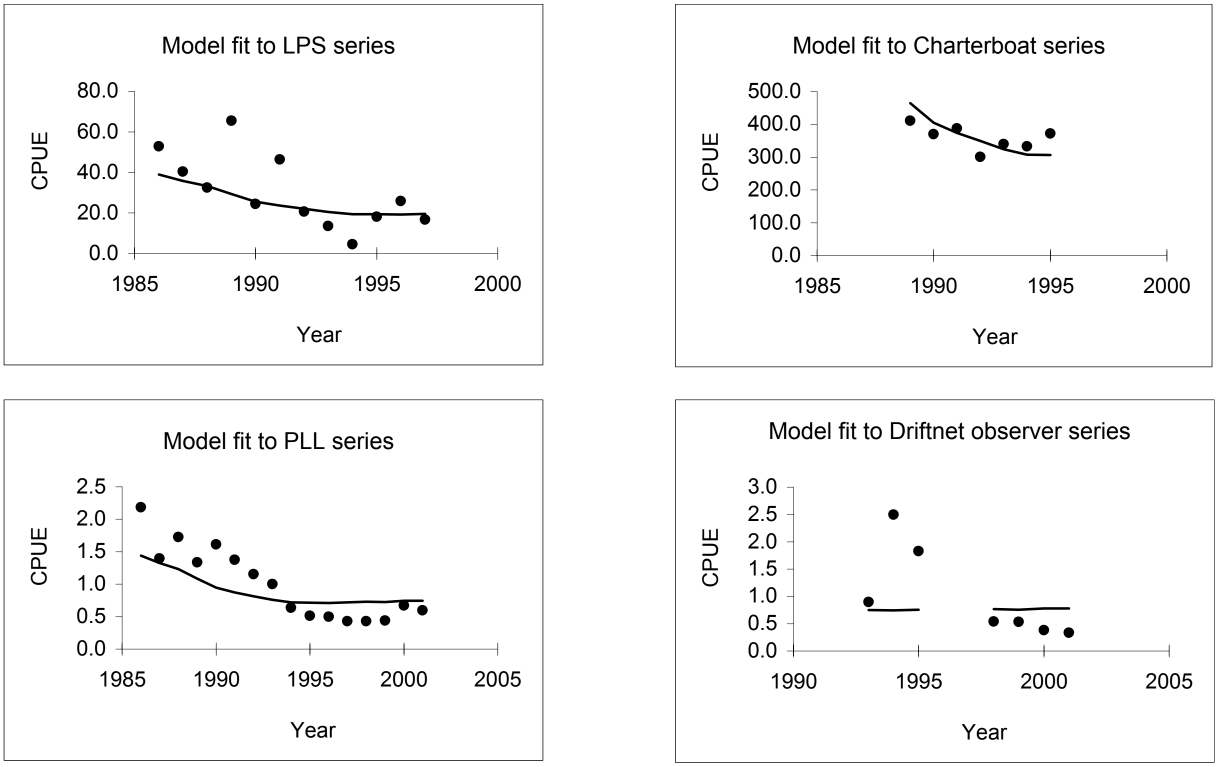


Figure 39 (continued). WinBUGS SSSPM fits to the individual CPUE series of the baseline scenario for the large coastal shark complex.

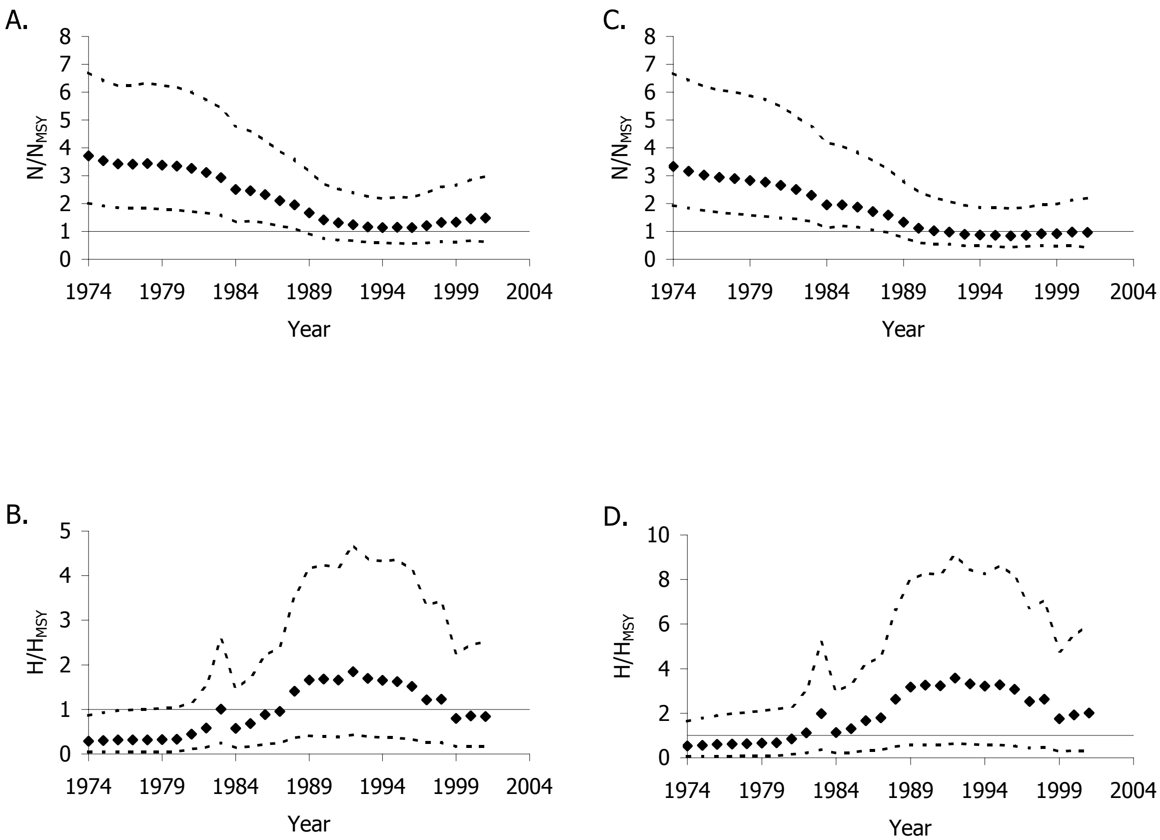


Figure 40. Estimated relative abundance (A and C) and harvest rate (B and D) trajectories for the large coastal shark complex under the baseline scenario using the state-space lagged recruitment, survival, and growth model (SSLRSG) in winBUGS. The panels on the left side correspond to the form of the model model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

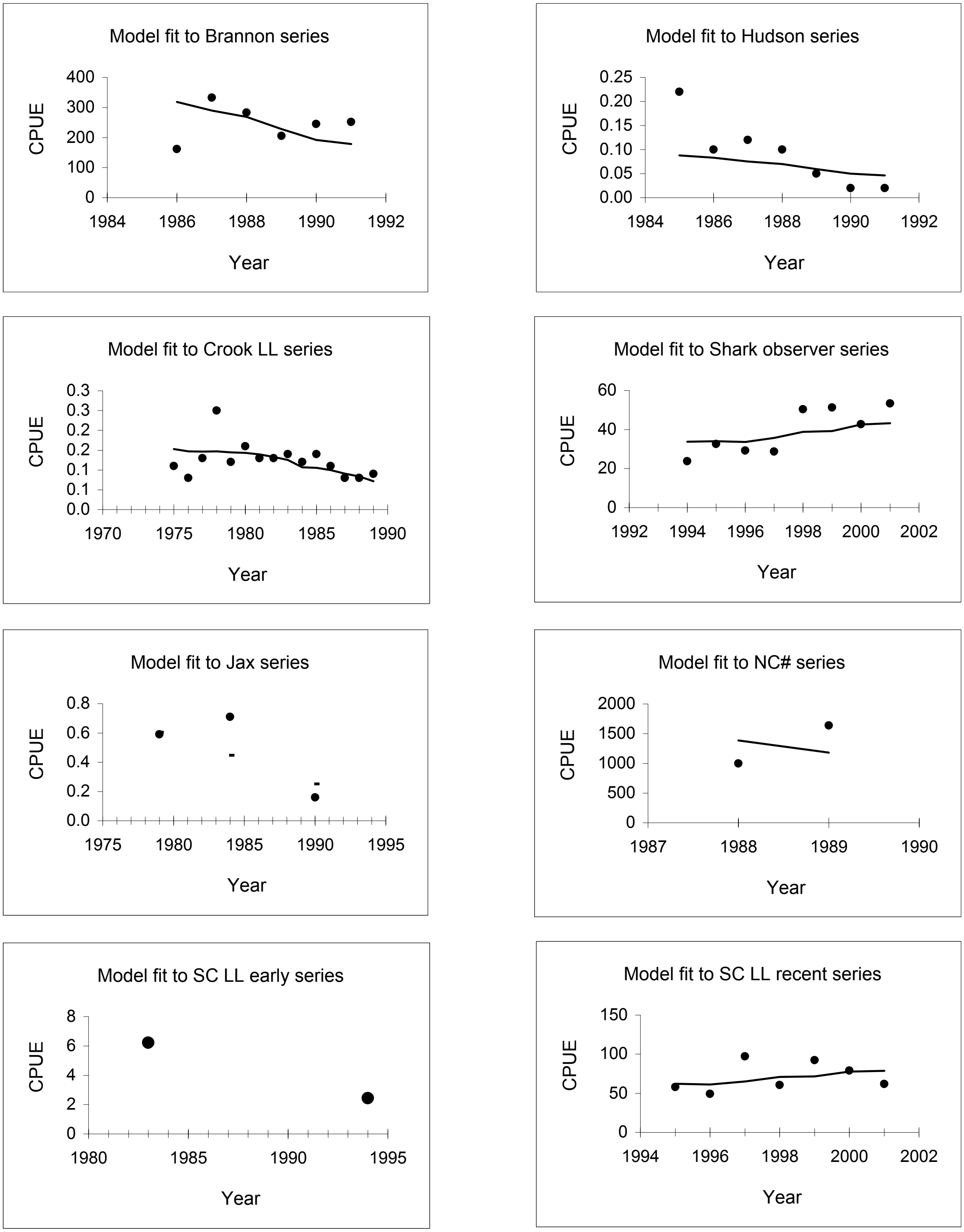


Figure 41. WinBUGS SSLRSG model fits to the individual CPUE series of the baseline scenario for the large coastal shark complex.

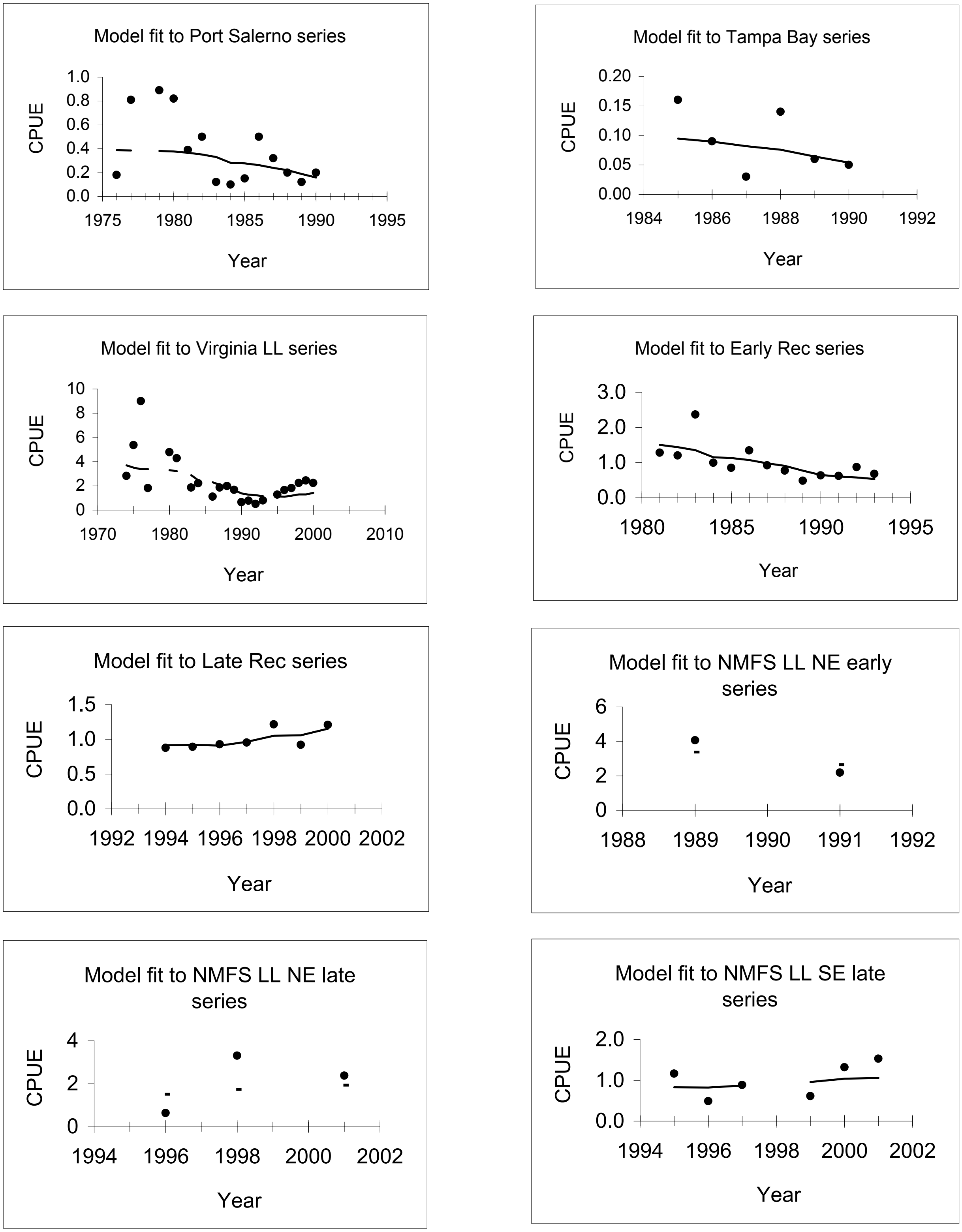


Figure 41 (continued). WinBUGS SSLRSG model fits to the individual CPUE series of the baseline scenario for the large coastal shark complex.

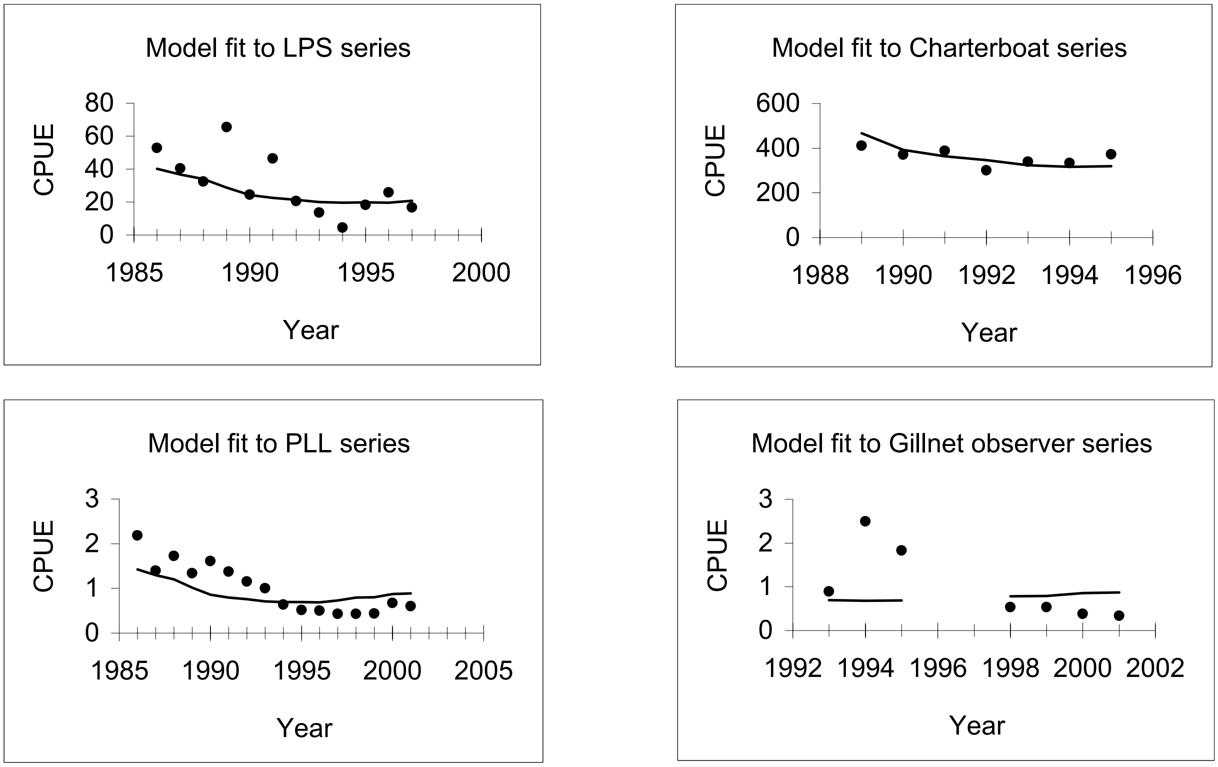


Figure 41 (continued). WinBUGS SSLRSG model fits to the individual CPUE series of the baseline scenario for the large coastal shark complex.

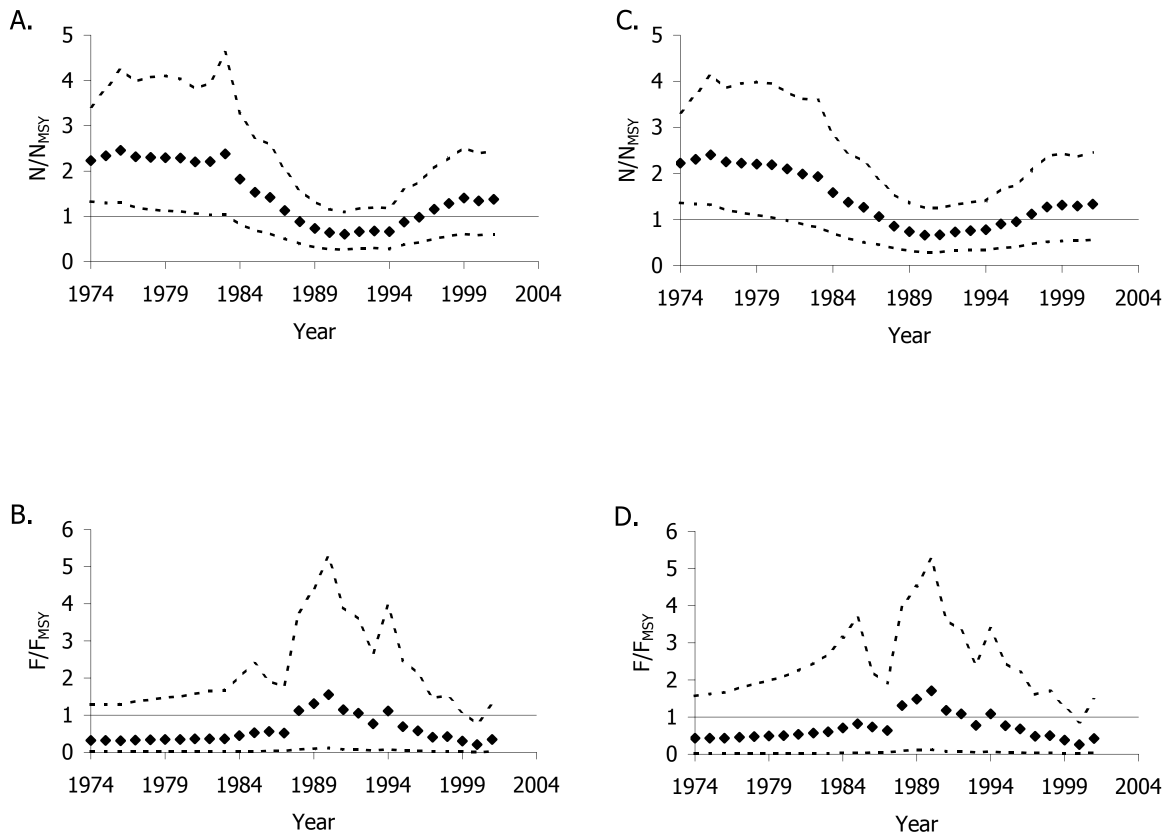


Figure 42. Estimated relative abundance (A and C) and fishing mortality rate (B and D) trajectories for the sandbar shark under the baseline scenario using the state-space surplus production model (SSSPM) in winBUGS. The panels on the left side correspond to the form of the model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

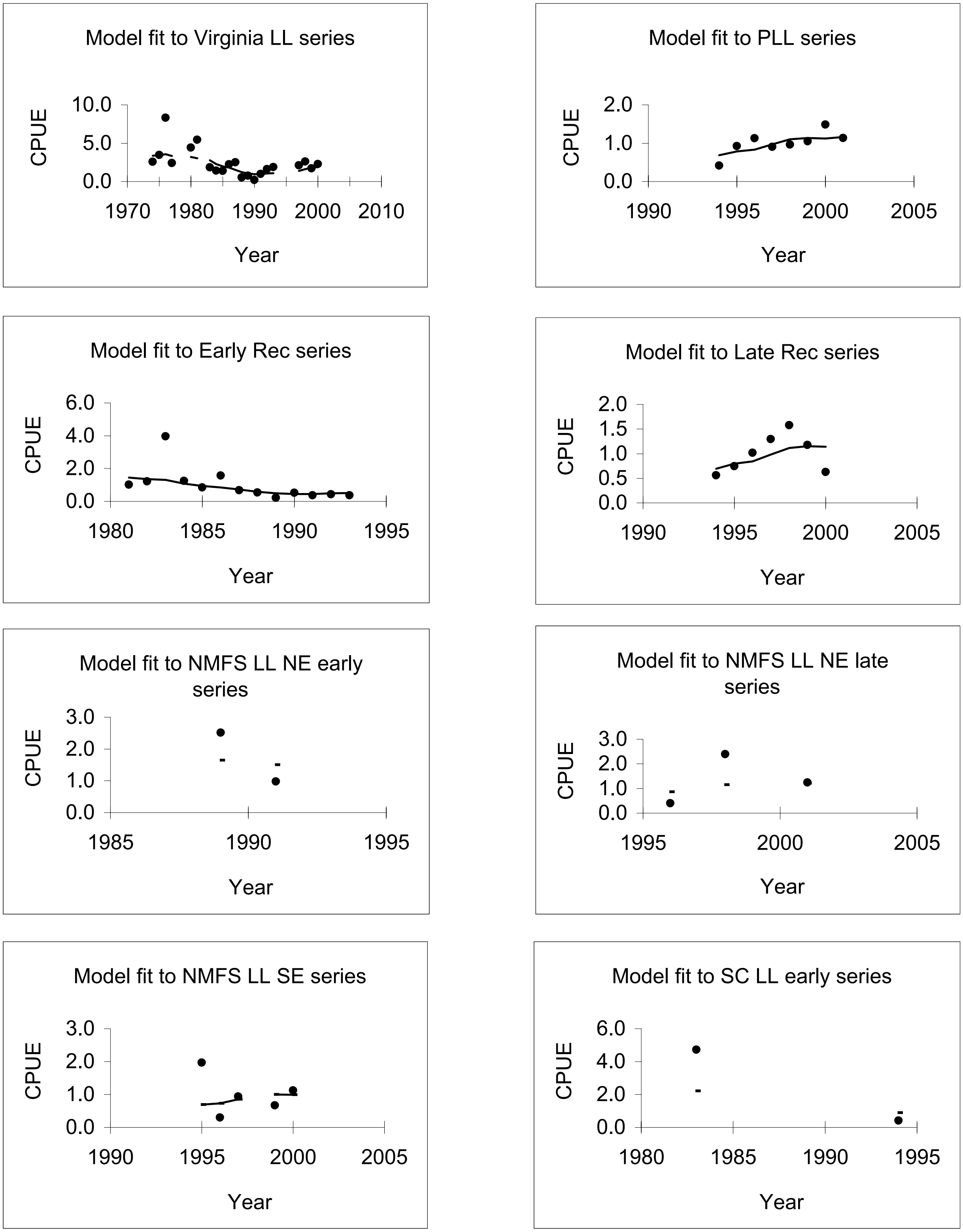
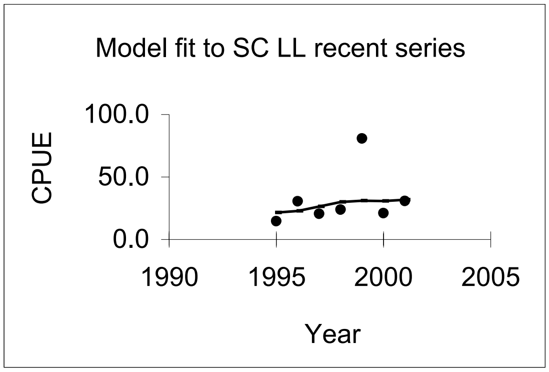


Figure 43. WinBUGS SSSPM fits to the individual CPUE series of the baseline scenario for sandbar shark.



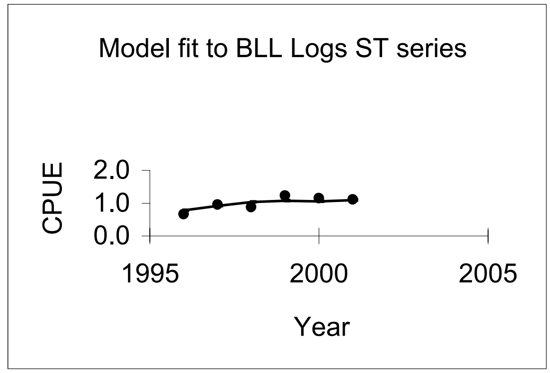


Figure 43 (continued). WinBUGS SSSPM fits to the individual CPUE series of the baseline scenario for sandbar shark.

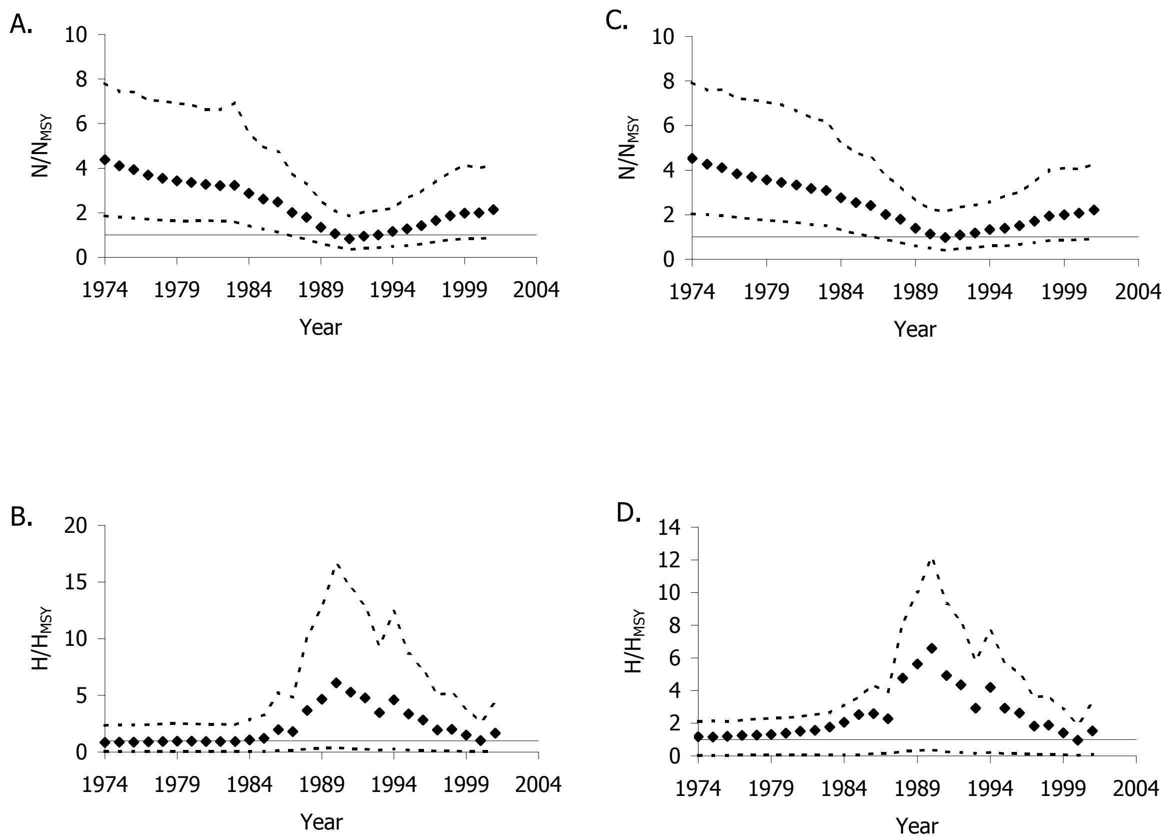


Figure 44. Estimated relative abundance (A and C) and harvest rate (B and D) trajectories for the sandbar shark under the baseline scenario using the state-space lagged recruitment, survival, and growth model (SSLRSG) in winBUGS. The panels on the left side correspond to the form of the model model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

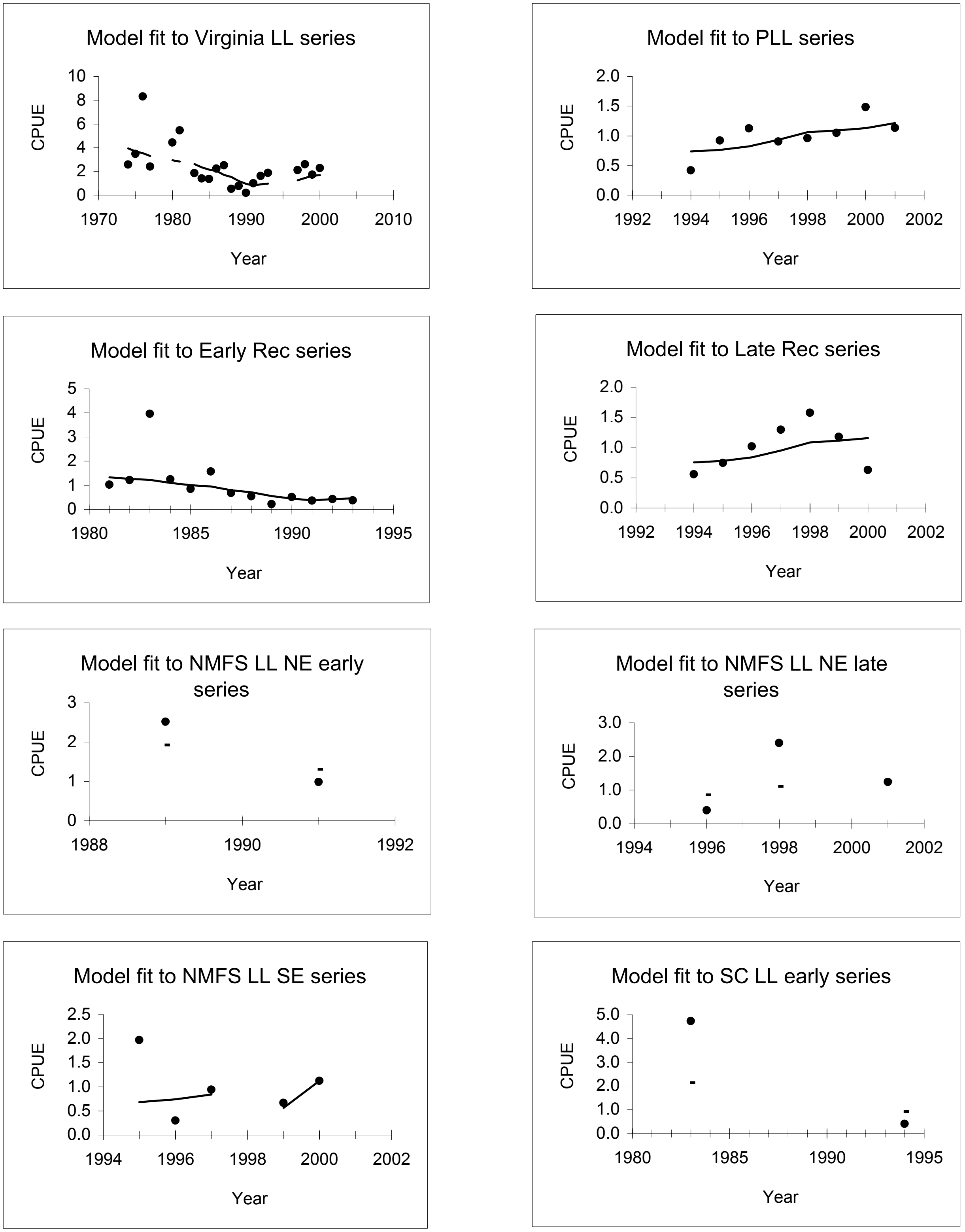
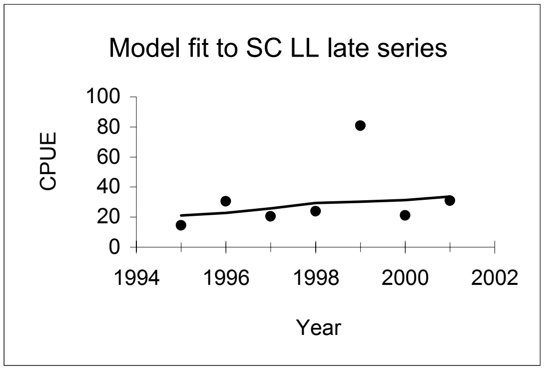


Figure 45. WinBUGS SSLRSG model fits to the individual CPUE series of the baseline scenario for sandbar shark.



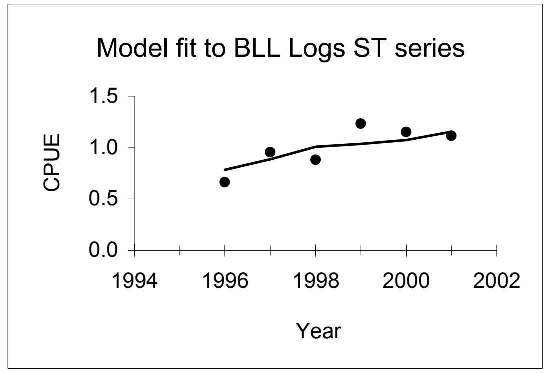


Figure 45 (continued). WinBUGS SSLRSG model fits to the individual CPUE series of the baseline scenario for sandbar shark.

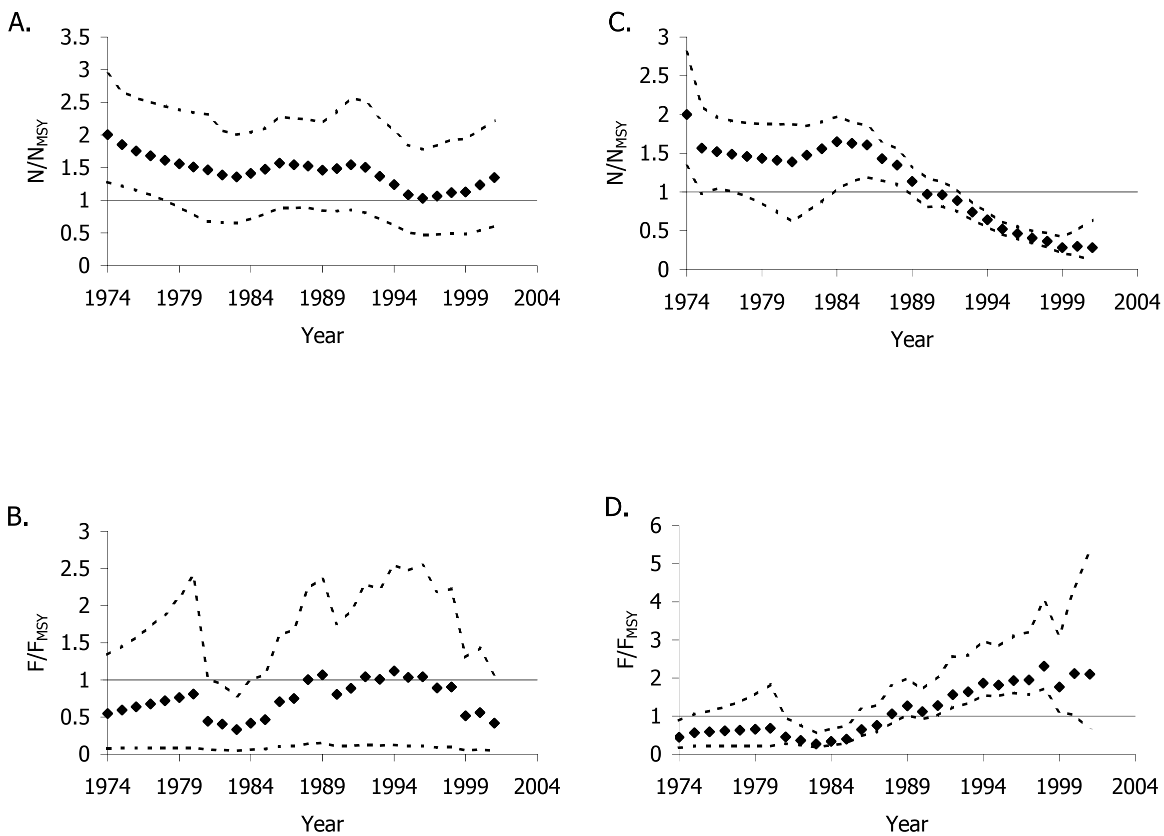


Figure 46. Estimated relative abundance (A and C) and fishing mortality rate (B and D) trajectories for the blacktip shark under the baseline scenario using the state-space surplus production model (SSSPM) in winBUGS. The panels on the left side correspond to the form of the model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

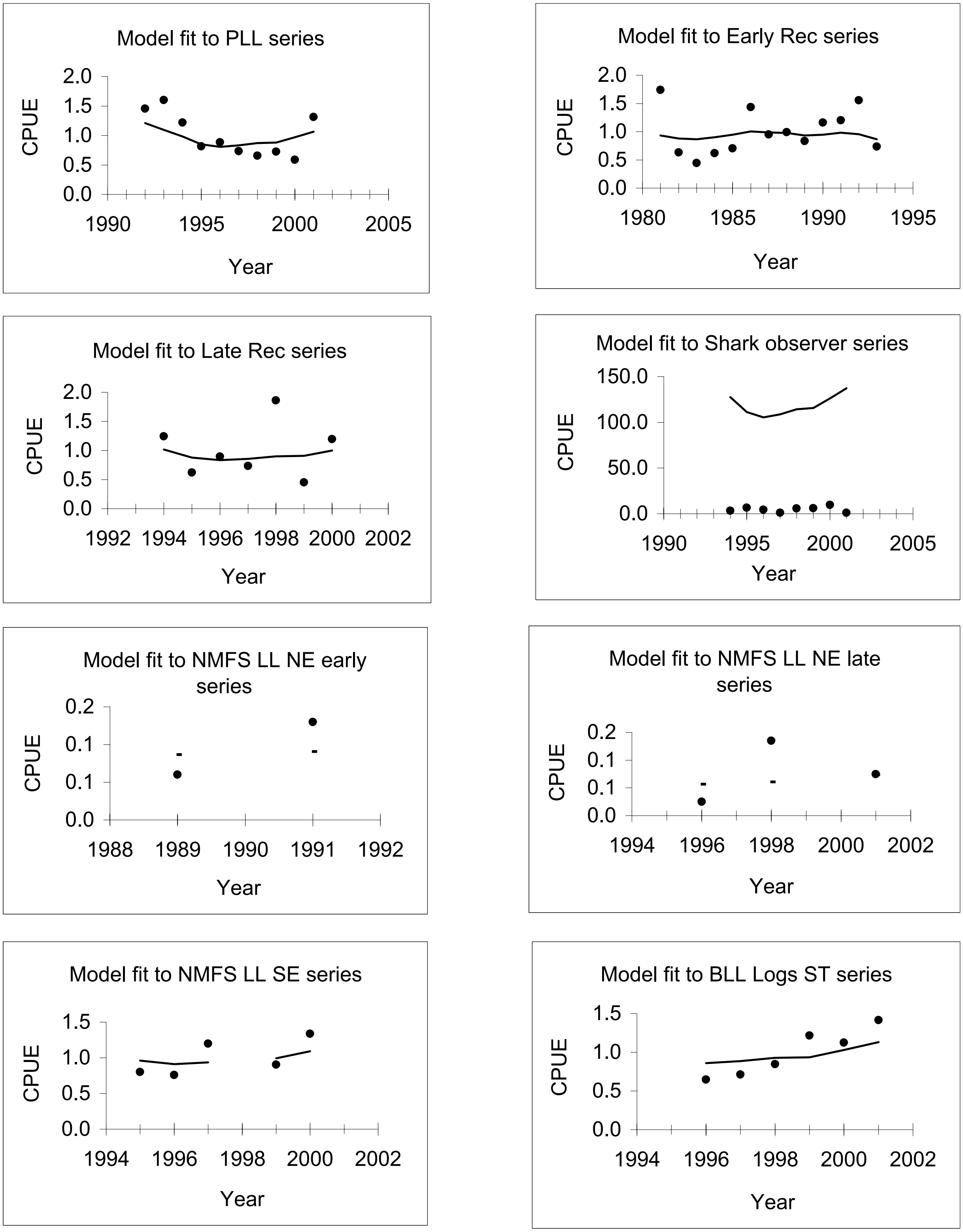


Figure 47. WinBUGS SSSPM fits to the individual CPUE series of the baseline scenario for blacktip shark.

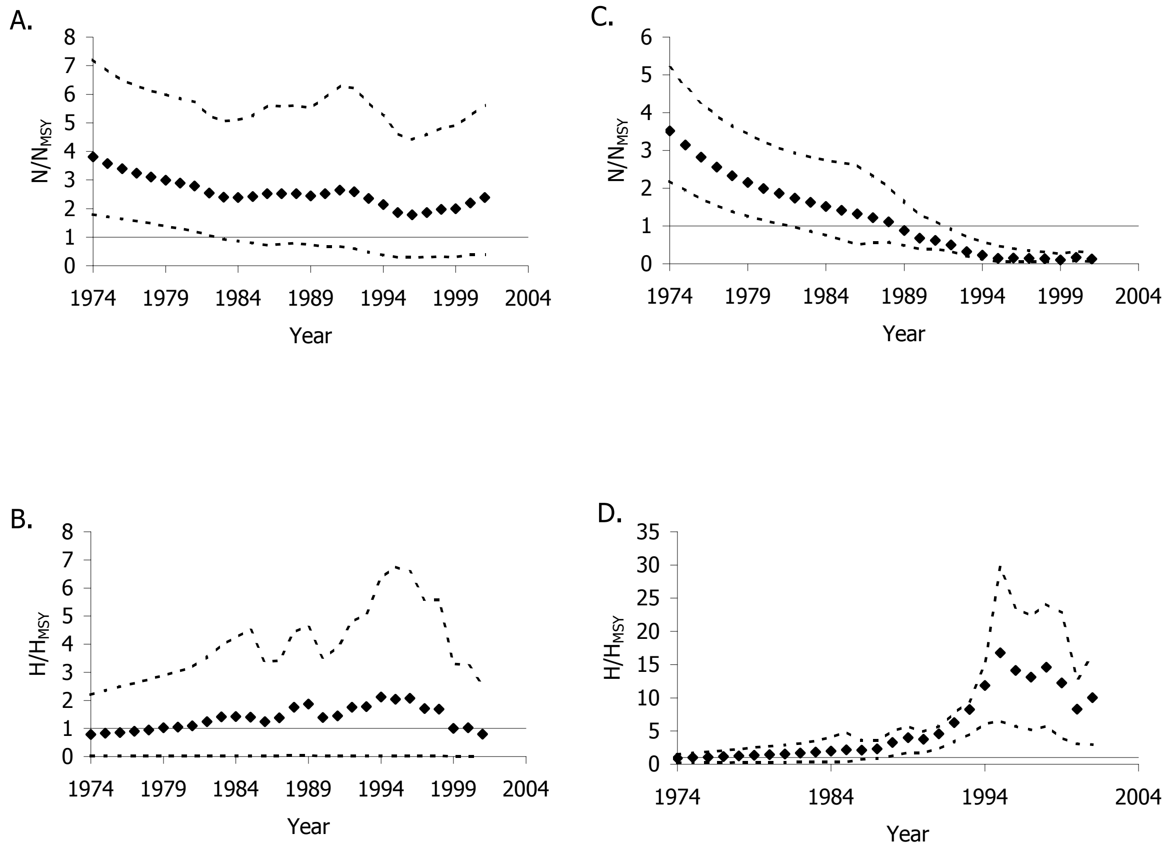


Figure 48. Estimated relative abundance (A and C) and harvest rate (B and D) trajectories for the blacktip shark under the baseline scenario using the state-space lagged recruitment, survival, and growth model (SSLRSG) in winBUGS. The panels on the left side correspond to the form of the model model with one τ^2 (observation error) for each CPUE series; those on the right to the form with one τ^2 for all CPUE series. Values shown are means with 2.5th and 97.5th percentiles. The horizontal line at 1 denotes the MSY (MSC) level.

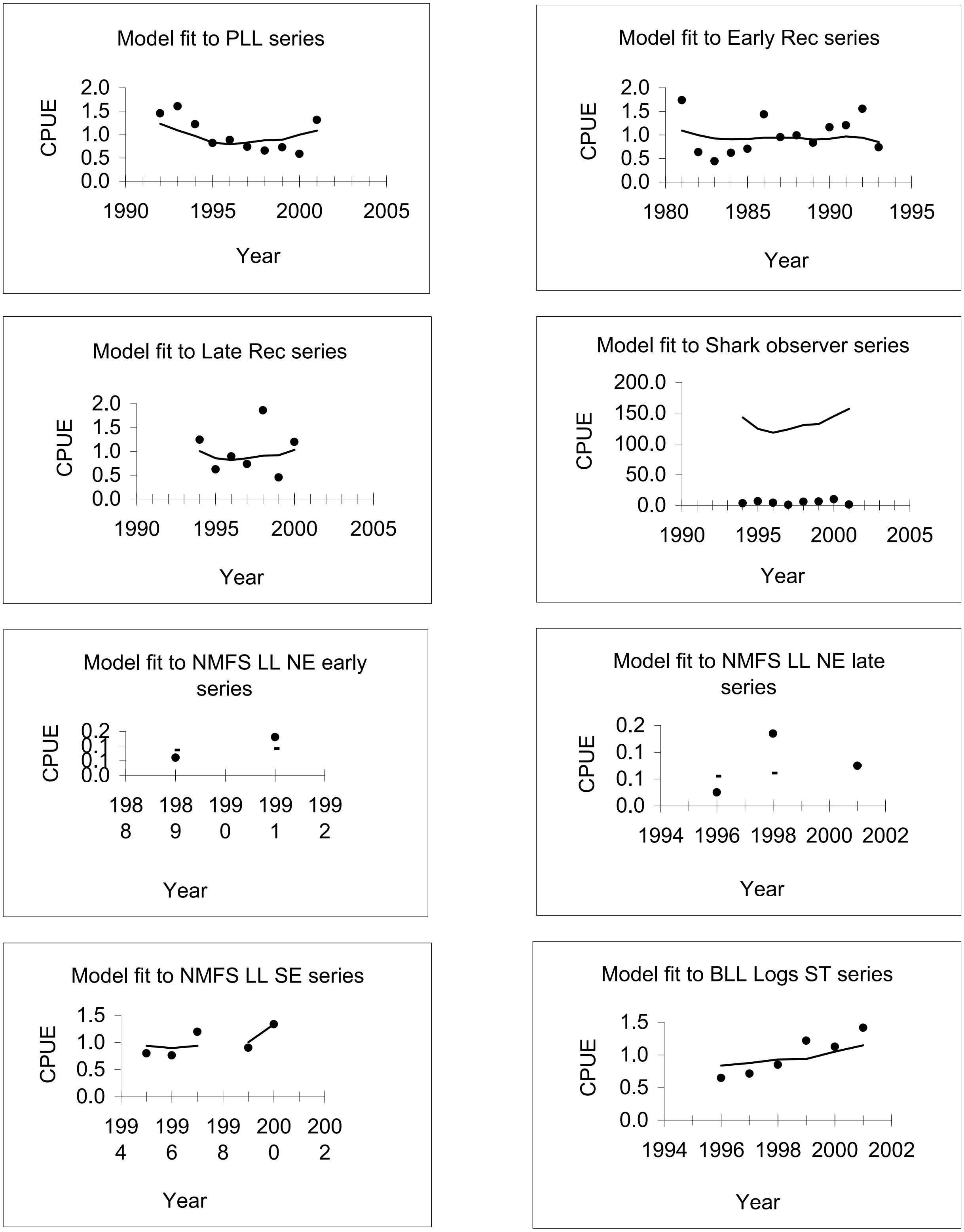
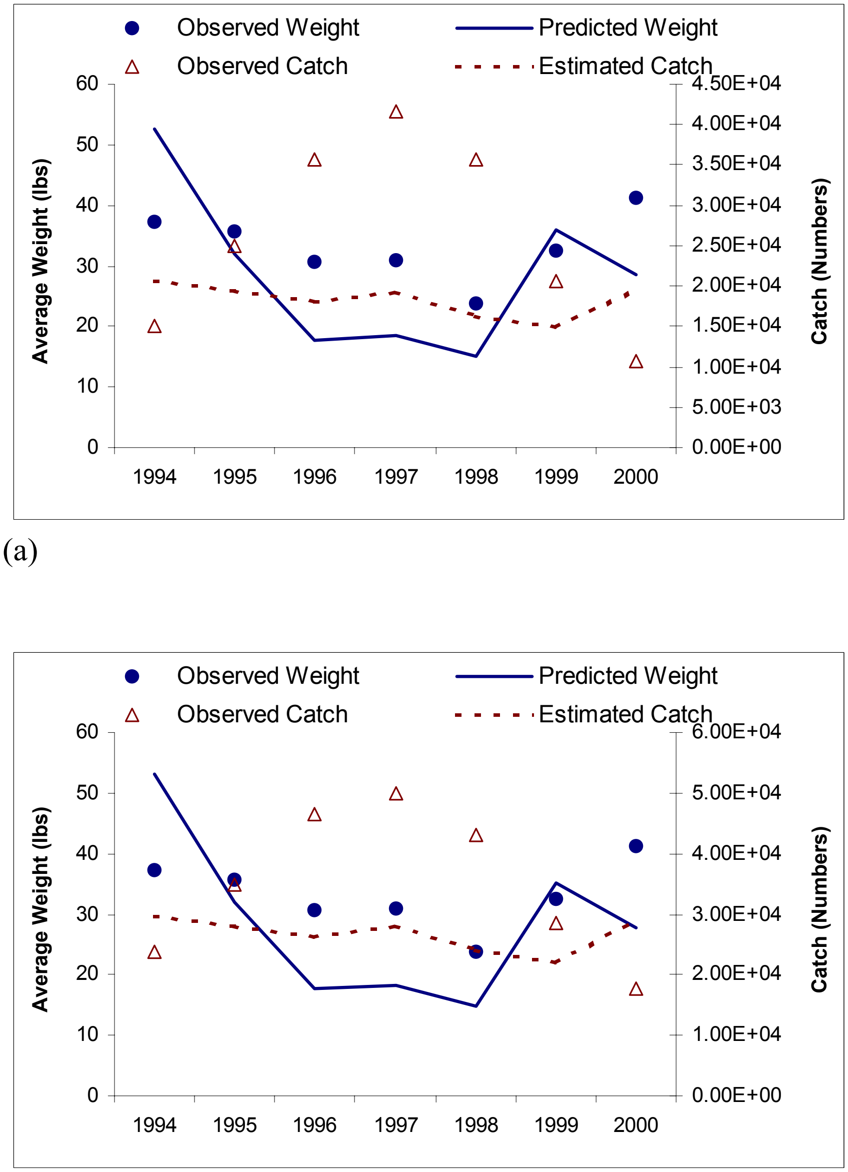


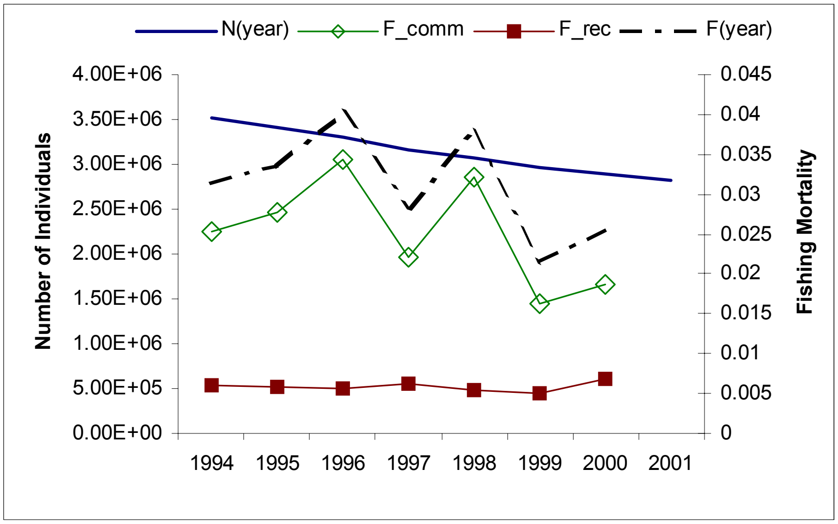
Figure 49. WinBUGS SSLRSG model fits to the individual CPUE series of the baseline scenario for blacktip shark.



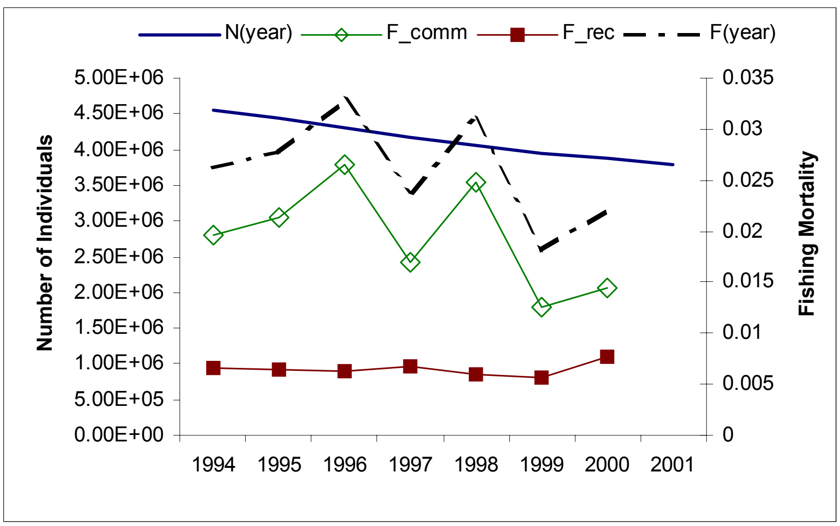
(a)

(b)

Figure 50. Fit to observed weight or catch of Sandbar shark for (a) updated or (b) baseline MLE model.



(a)



(b)

Figure 51. Annual estimates of commercial fishing mortality (F_comm.), recreational fishing mortality (F_rec), annual fishing mortality (F(year)), and population size (N(year)) for Sandbar shark MLE models. (a) updated model; (b) baseline model.

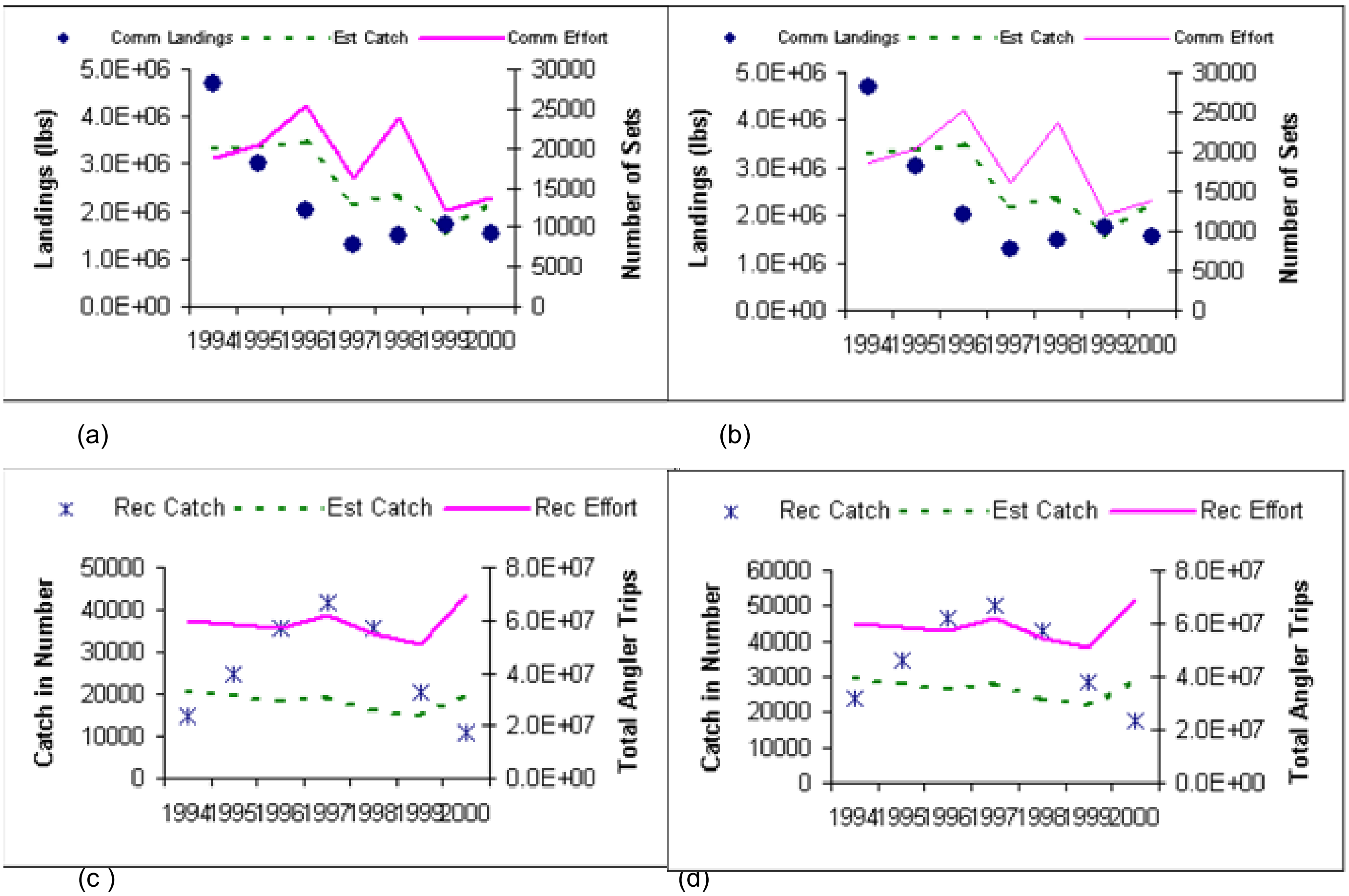
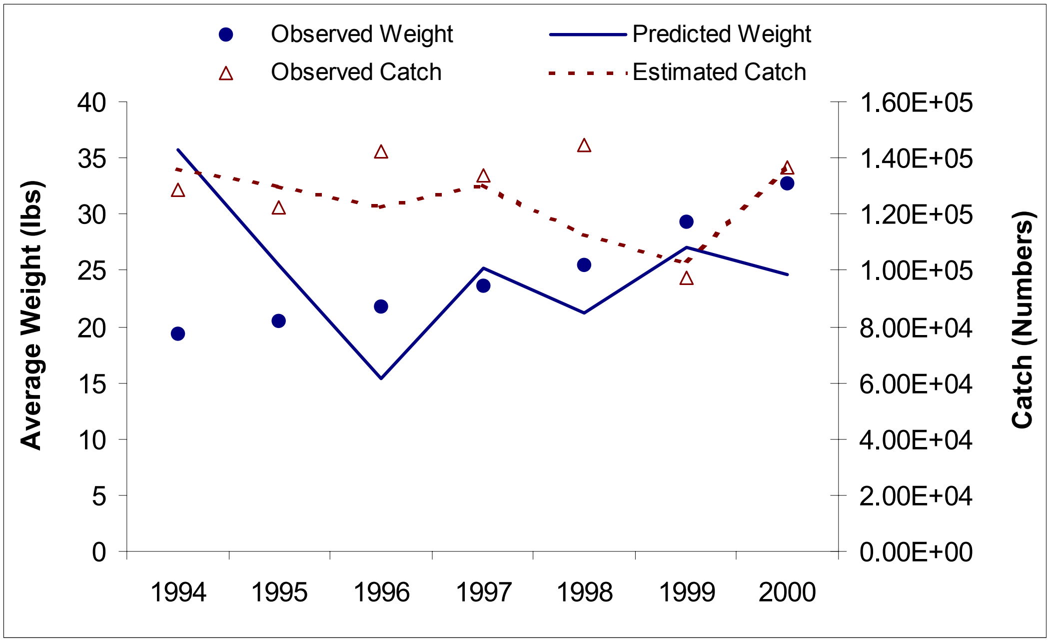
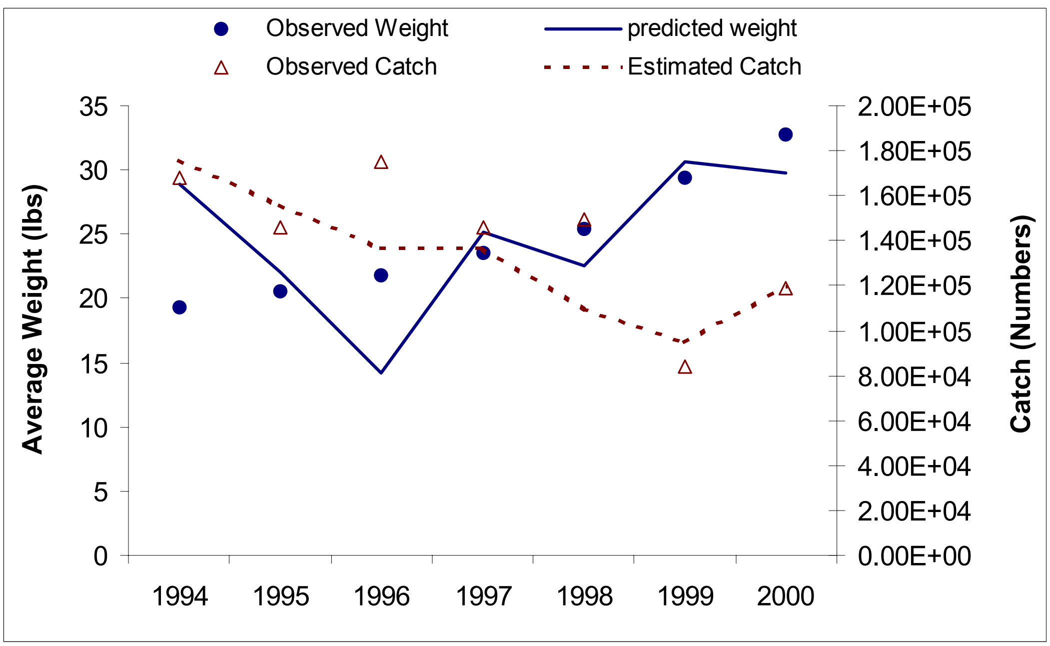


Figure 52. Fit to observed landings of Sandbar shark for (a), (c) updated and (b), (d) baseline MLE models. The annual effort is superimposed as a solid line.

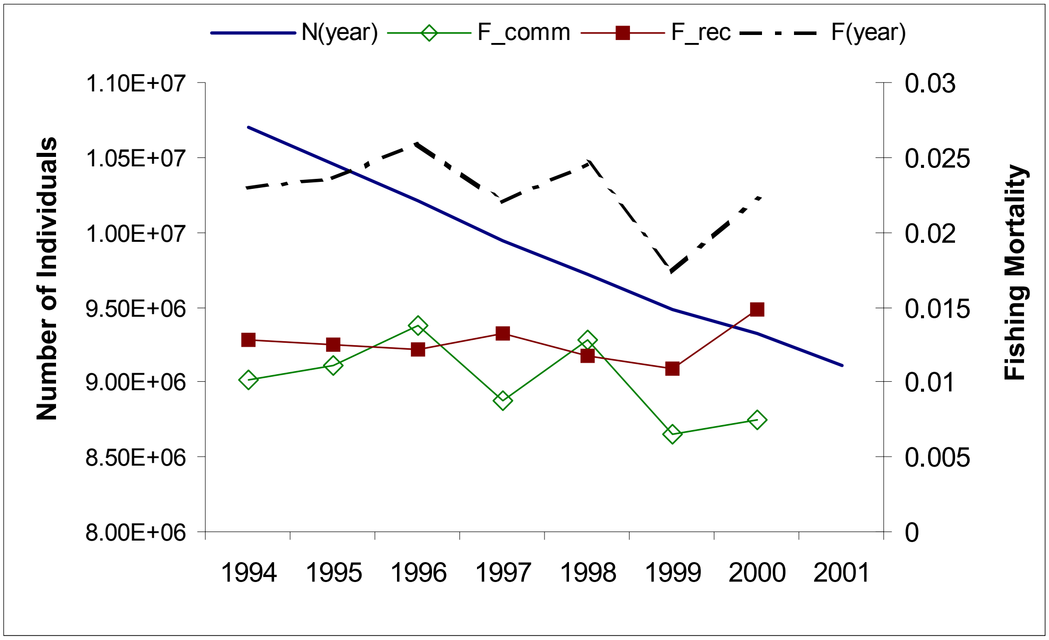


(a)

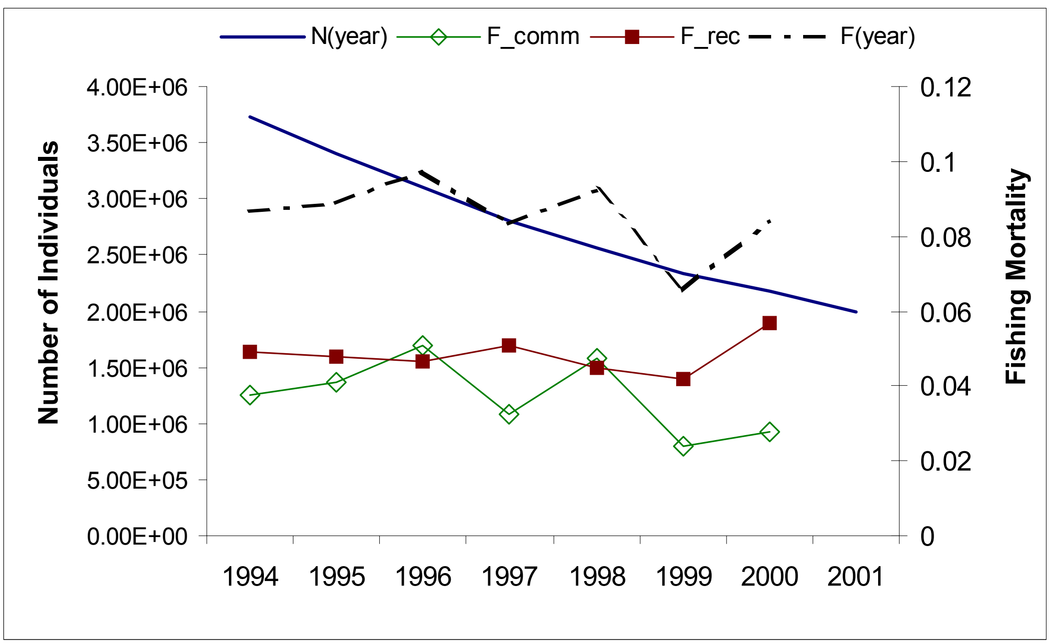


(b)

Figure 53. Fit to observed weight or catch of Blacktip shark for (a) updated or (b) baseline MLE model.



(a)



(b)

Figure 54. Annual estimates of commercial fishing mortality (F_comm.), recreational fishing mortality (F_rec), annual fishing mortality (F(year)), and population size (N(year)) for Blacktip shark MLE models. (a) updated model; (b) baseline model.

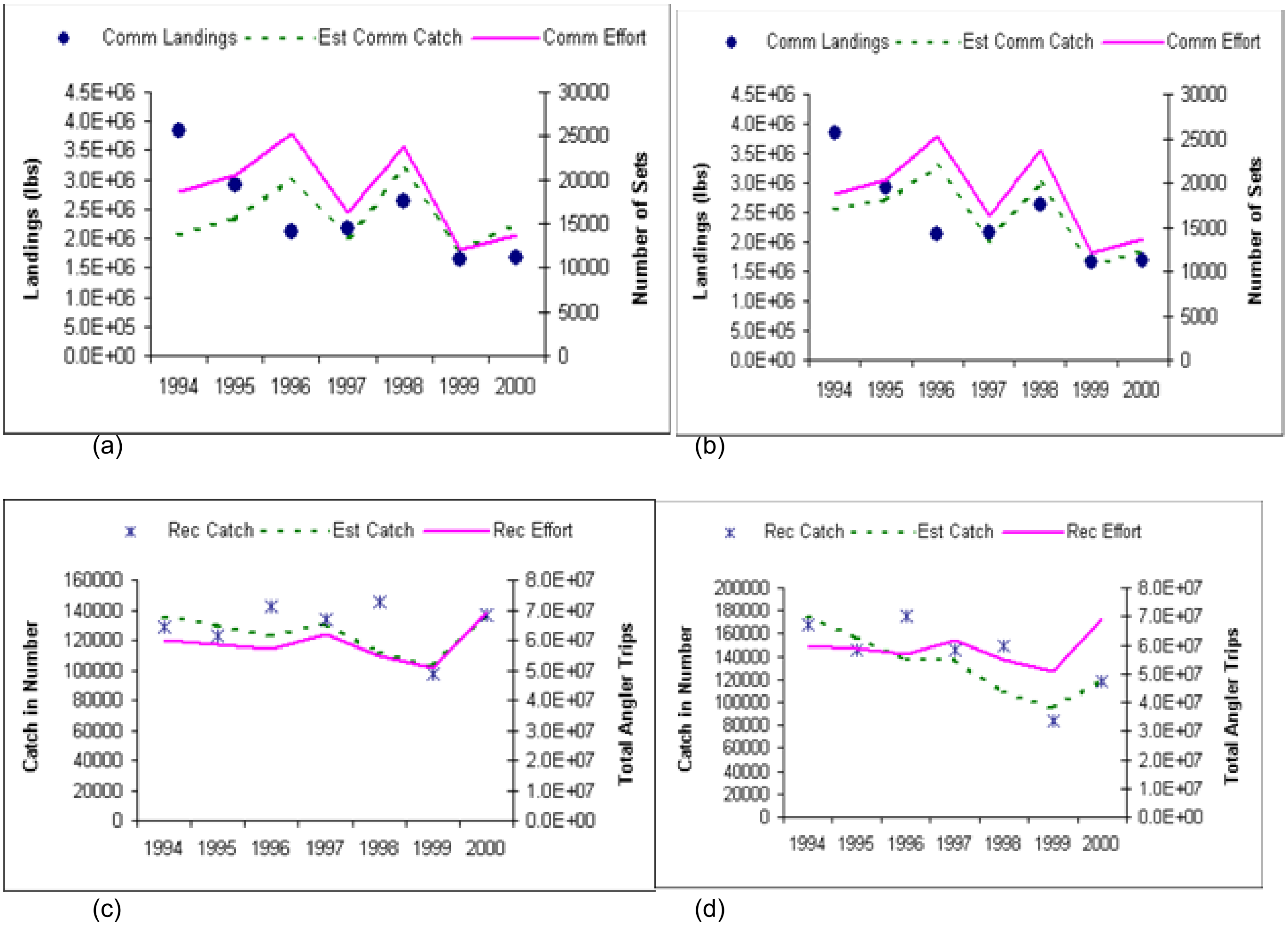


Figure 55. Fit to observed landings of Blacktip shark for (a), (c) updated and (b), (d) baseline MLE models. The annual effort is superimposed as a solid line.

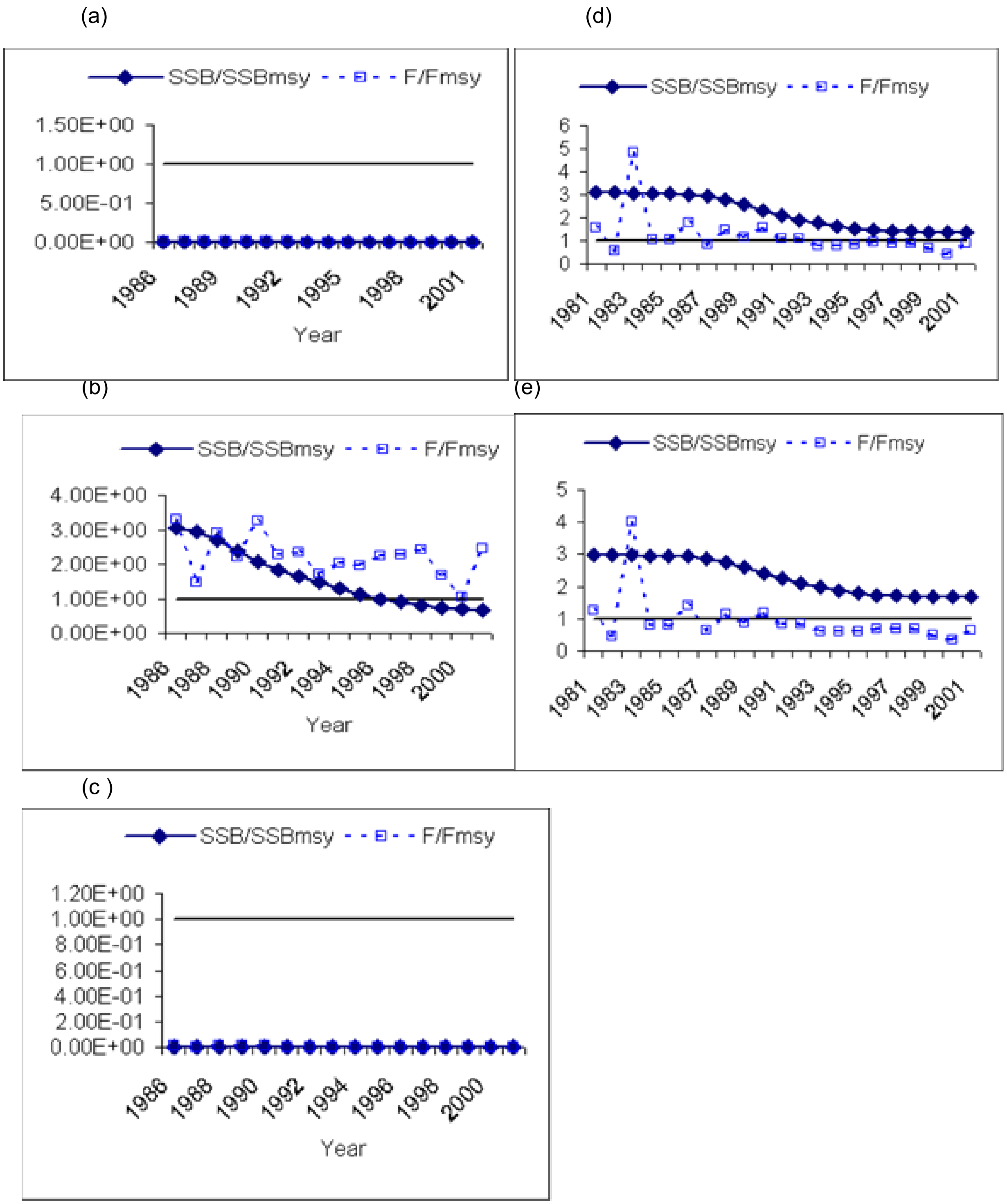


Figure 56. Trajectory of B/Bmsy and F/Fmsy for all Sandbar Updated ASPM models using (a) all indices, (b) fishery-dependent indices, or (c) fishery-independent indices; and for Sandbar Baseline models using (d) all indices or (e) fishery-independent indices.

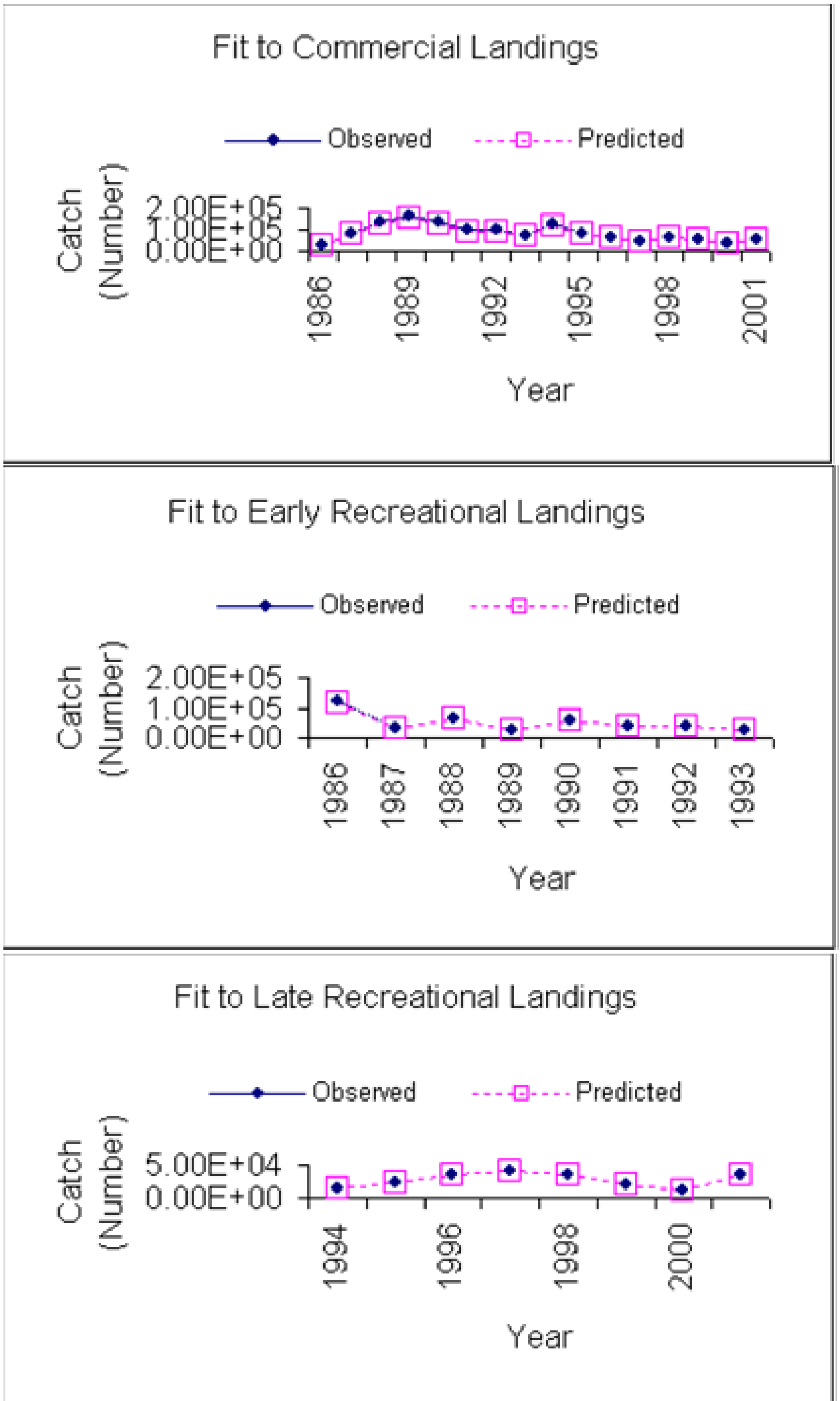
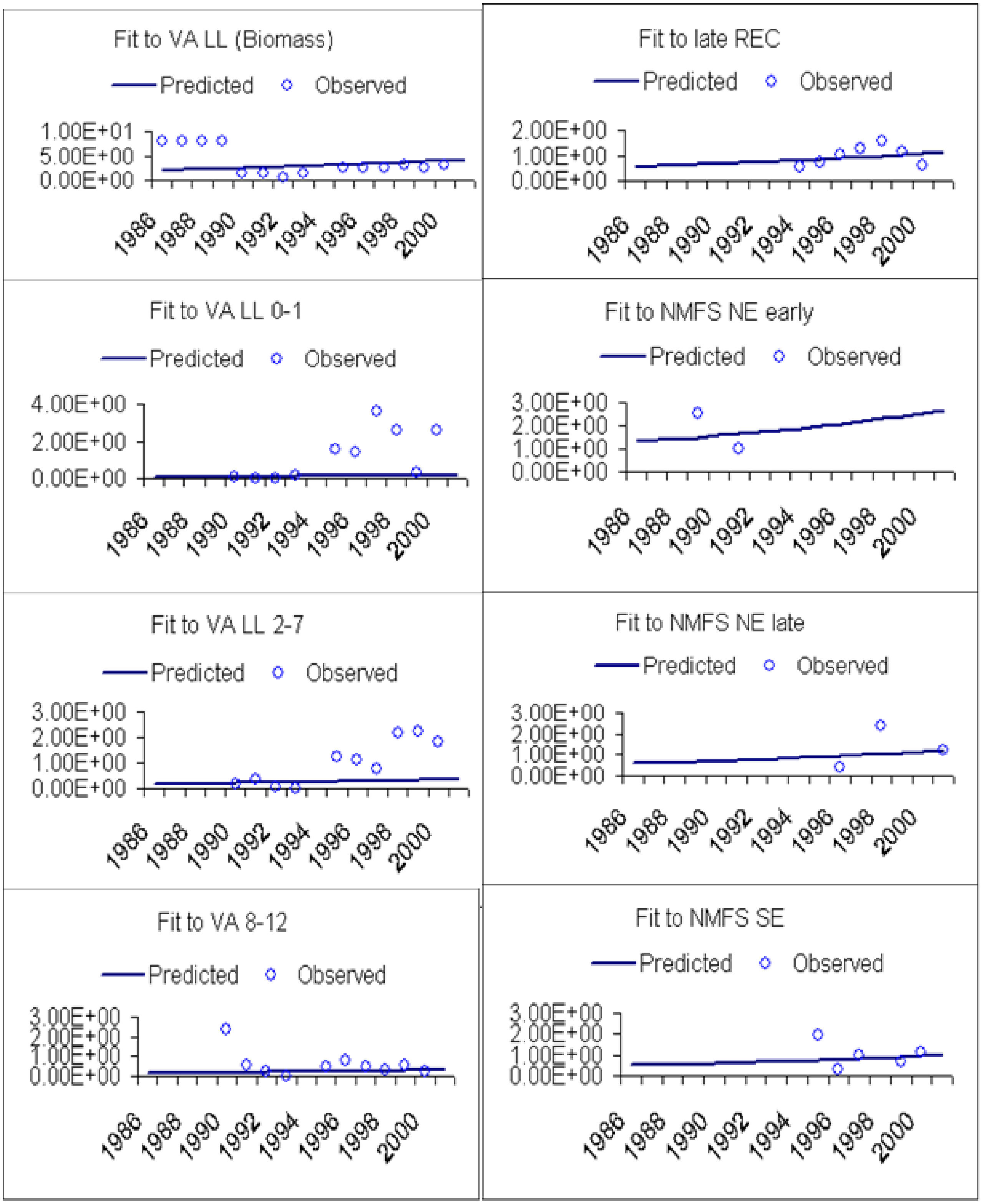


Figure 57. Fit of Sandbar Updated ASPM model to catches using all CPUE indices.


Fit to VA LL (Biomass)
Predicted
Observed
1.00E+01
5.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to late REC
Predicted
Observed
2.00E+00
1.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to VA LL 0-1
Predicted
Observed
4.00E+00
2.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to NMFS NE early
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to VA LL 2-7
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to NMFS NE late
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to VA 8-12
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000
Fit to NMFS SE
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1986 1988 1990 1992 1994 1996 1998 2000

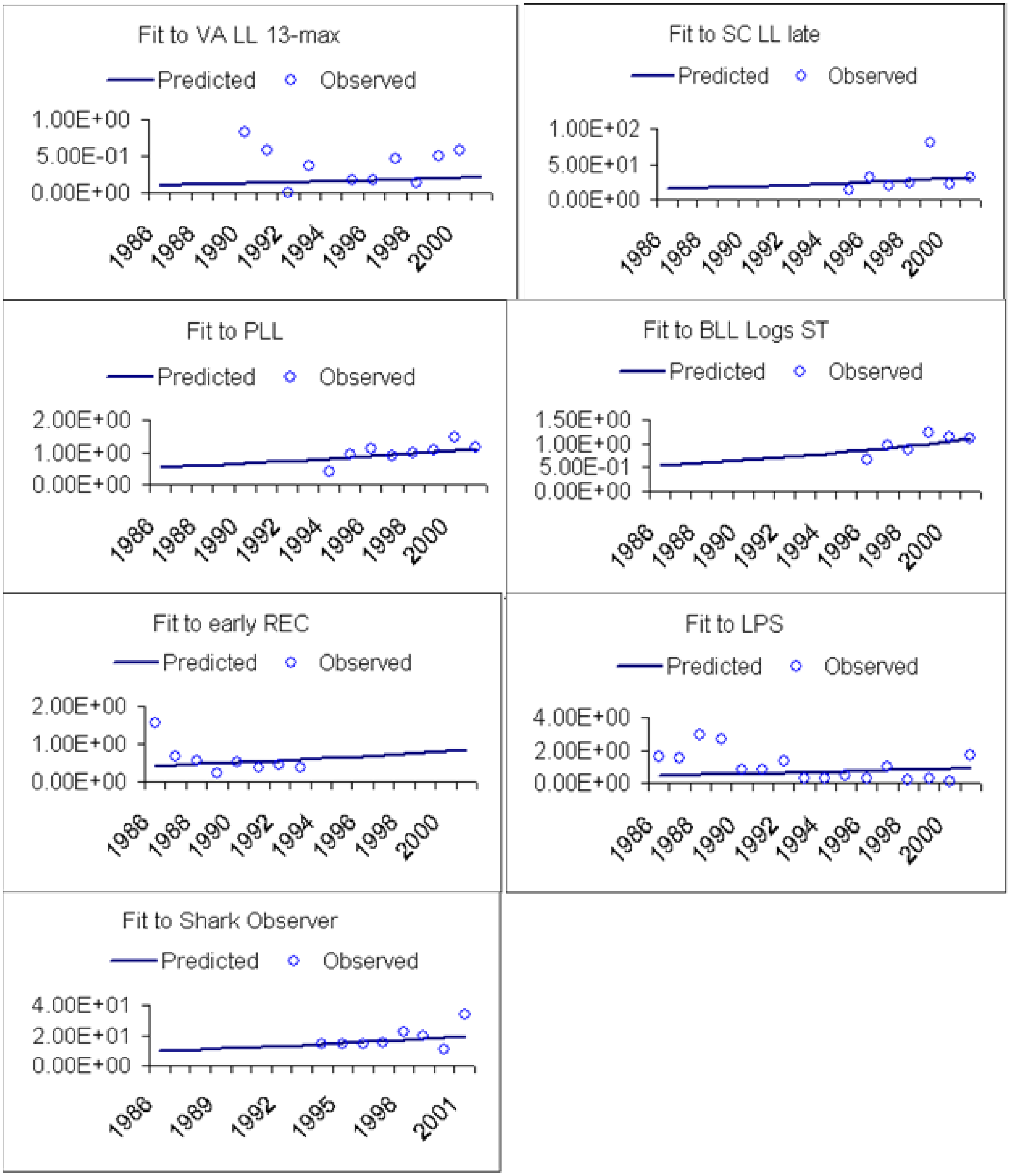
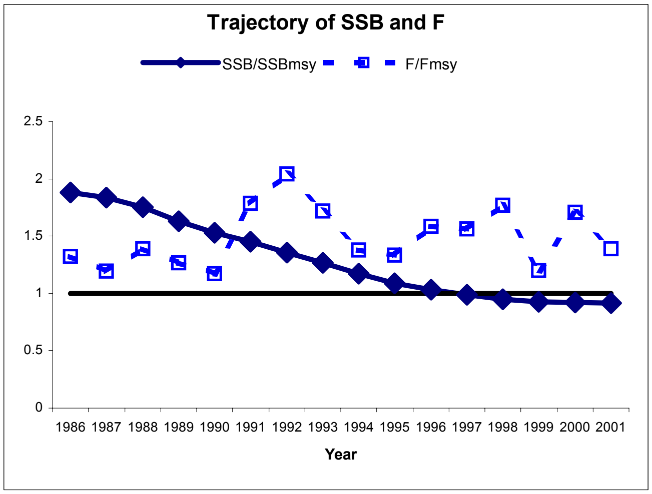
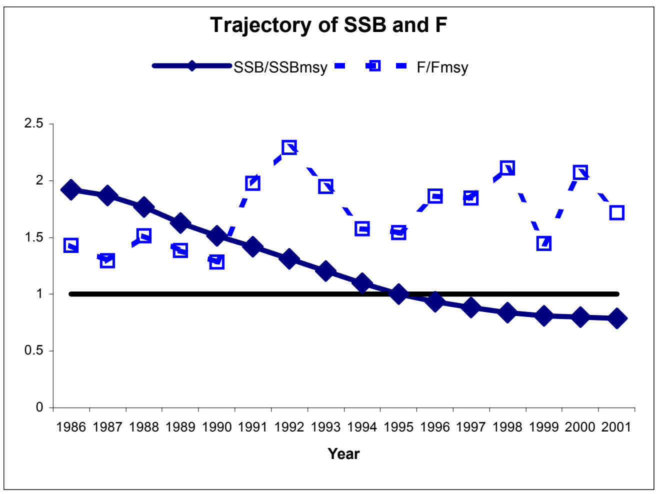


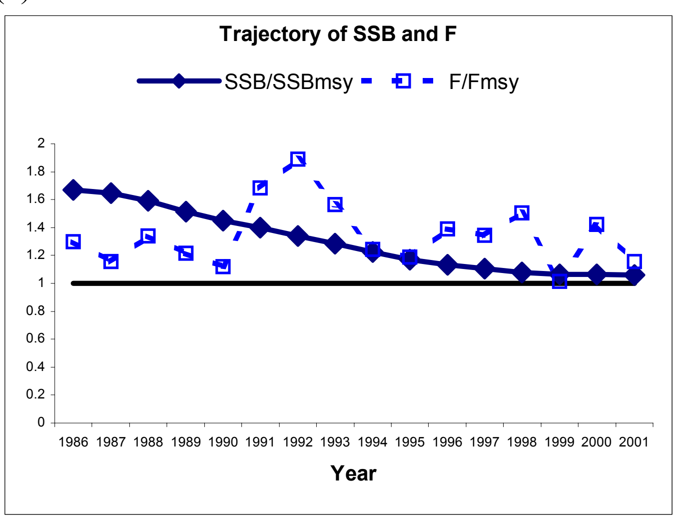
Figure 58. Fit to CPUE indices for Sandbar Updated ASPM model using all CPUE series.



(a)



(b)



(c)

Figure 59. Trajectory of B/Bmsy and F/Fmsy for all Blacktip Updated ASPM models using (a) all indices, (b) fishery-dependent indices, or (c) fishery-independent indices.

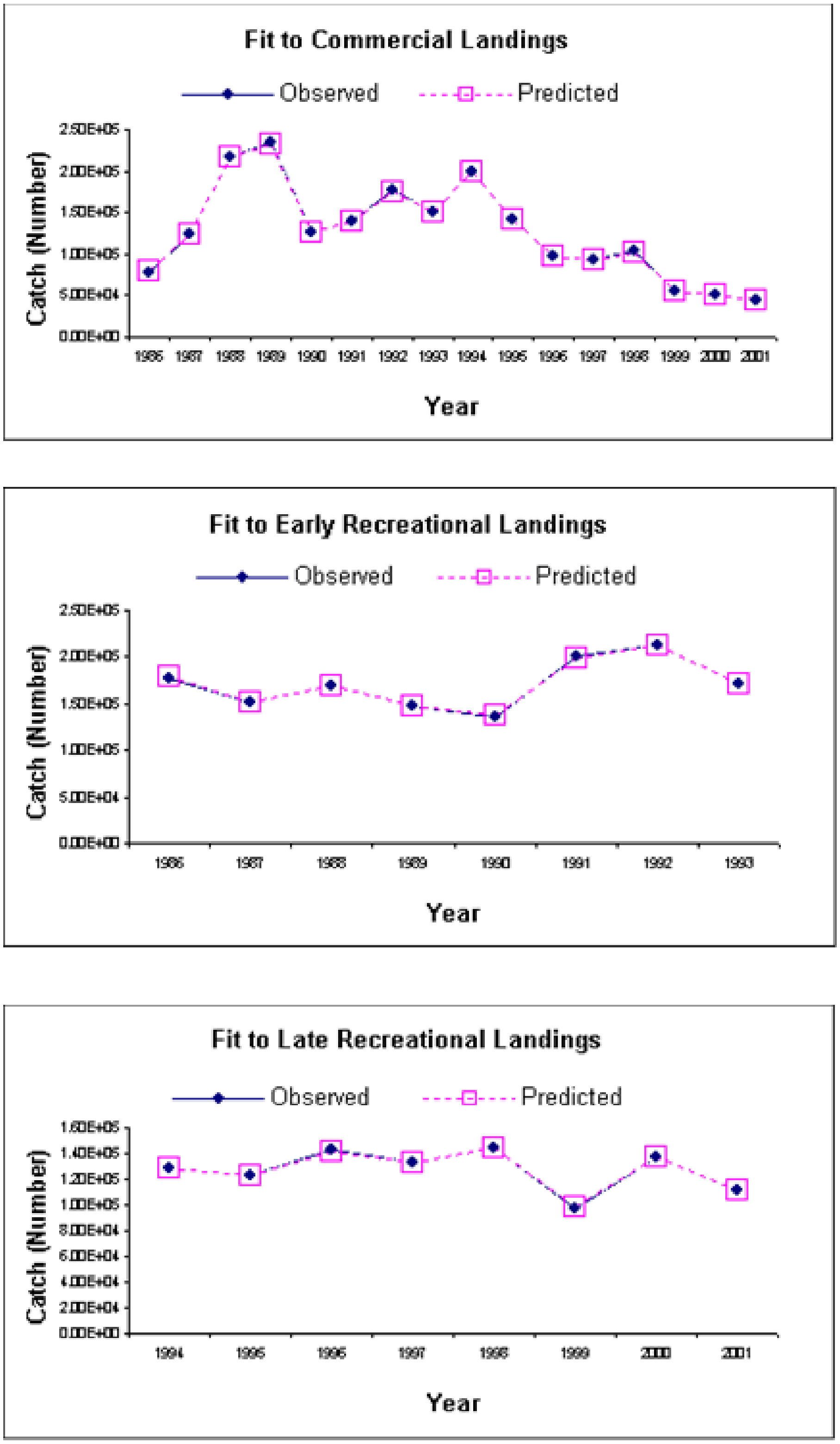
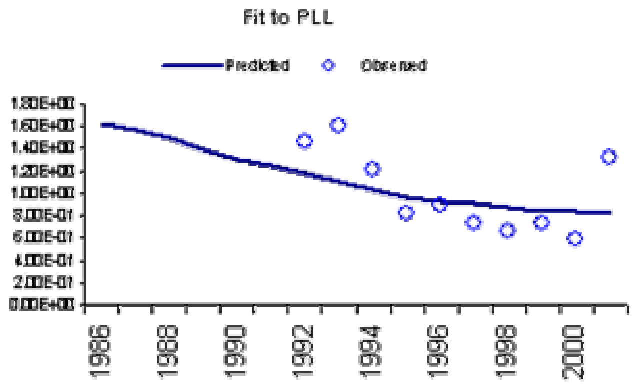
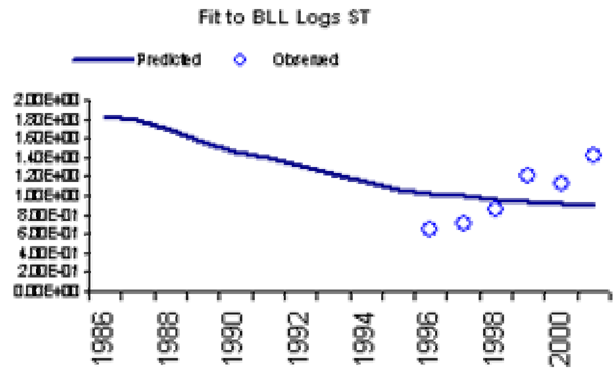
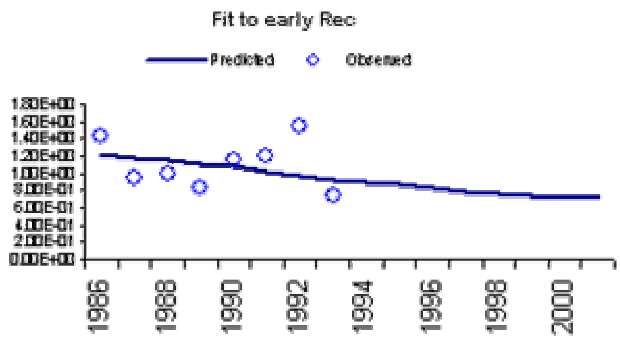
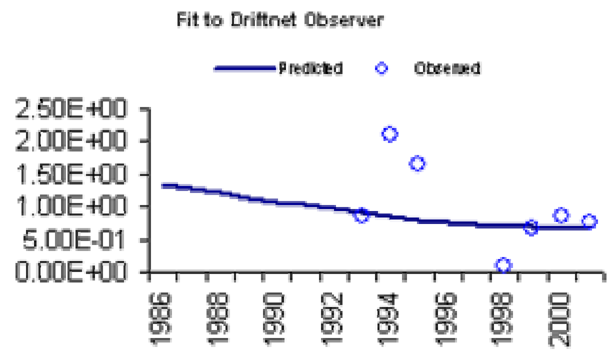


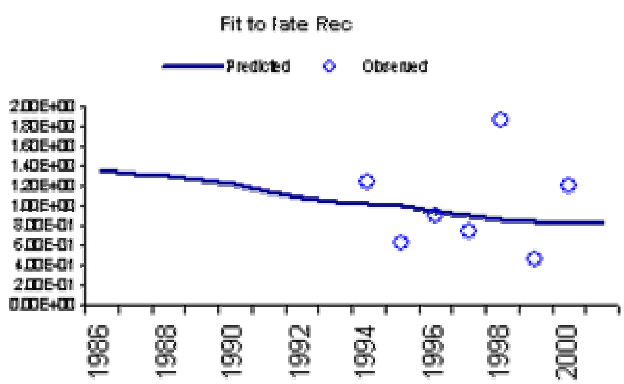
Figure 60. Fit to Blacktip Updated ASPM model using all CPUE indices.

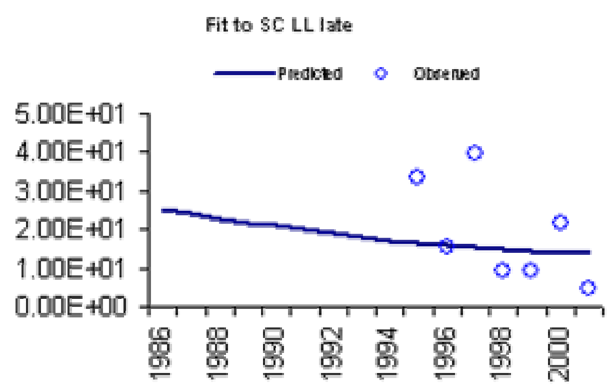

Fit to PLL
Predicted
Observed


Fit to BLL Logs ST
Predicted
Observed


Fit to early Rec
Predicted
Observed


Fit to Driftnet Observer
Predicted
Observed


Fit to late Rec
Predicted
Observed


Fit to SC LL late
Predicted
Observed

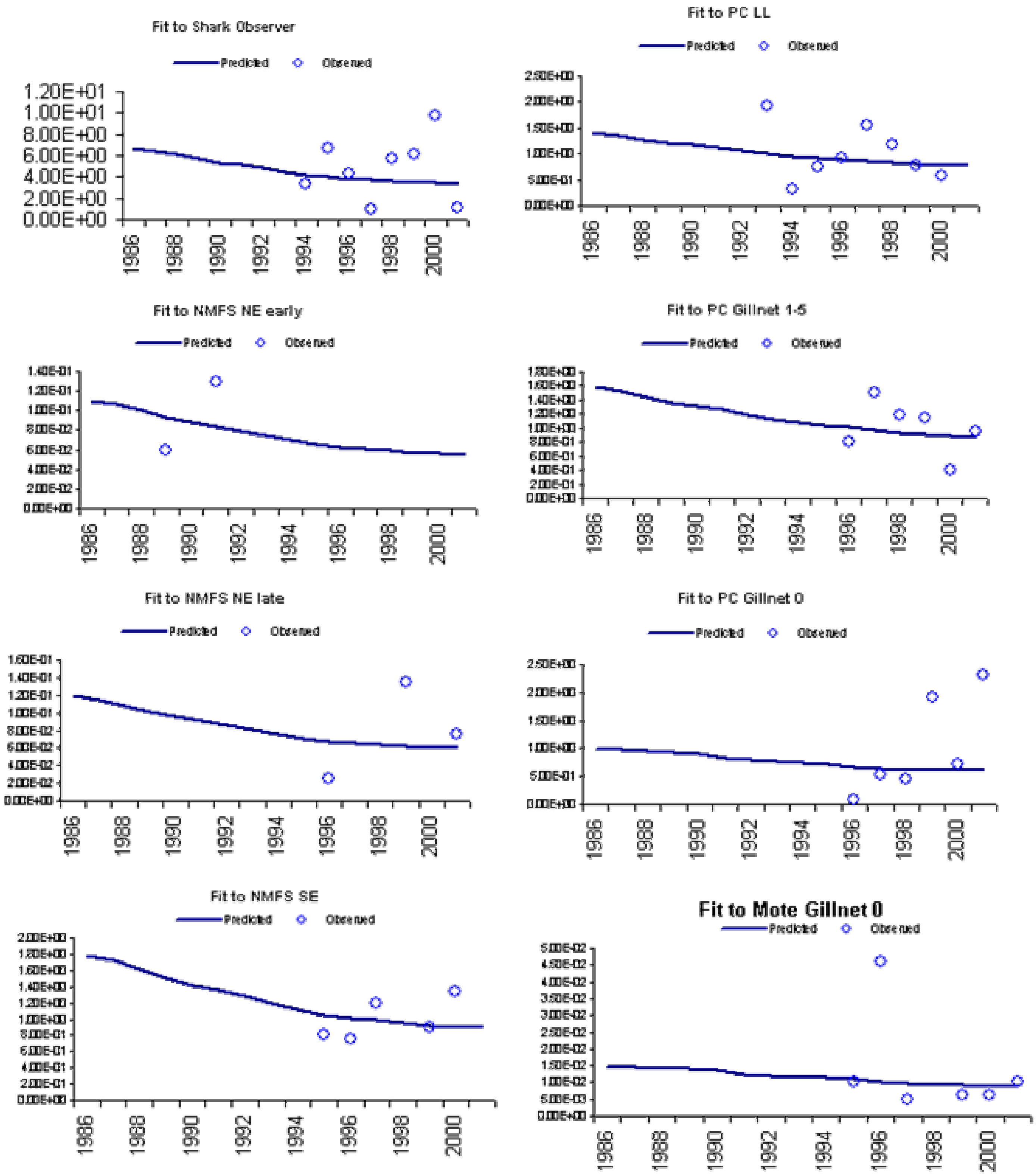


Figure 61. Fit to CPUE indices for Blacktip Updated ASPM model using all CPUE indices.

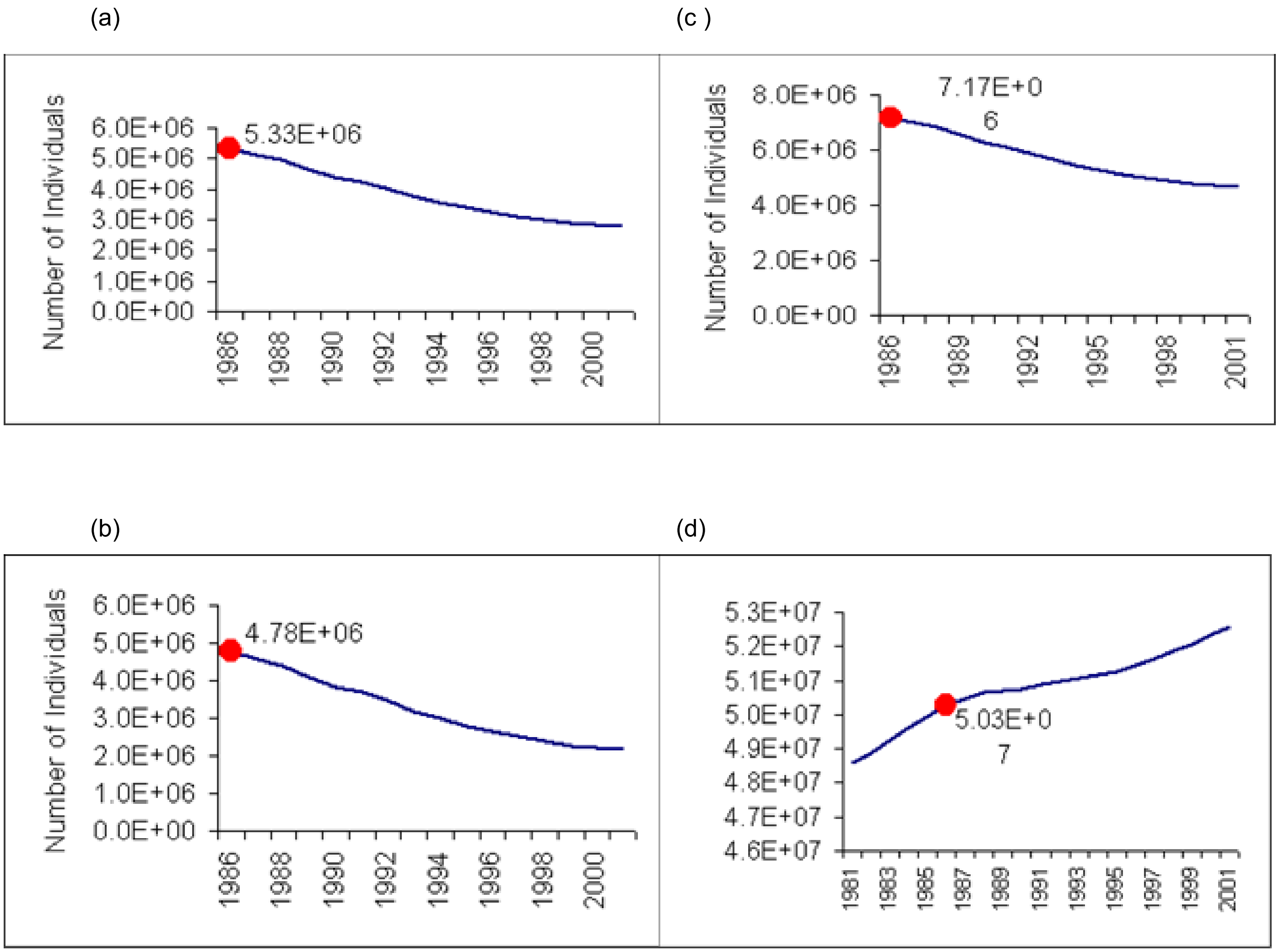


Figure 62. Trajectory of Population Size for all Blacktip ASPM models: (a) Updated with all CPUE series; (b) Updated with fishery-dependent series; (c) Updated with fishery-independent series; and (d) Baseline with all CPUE series.

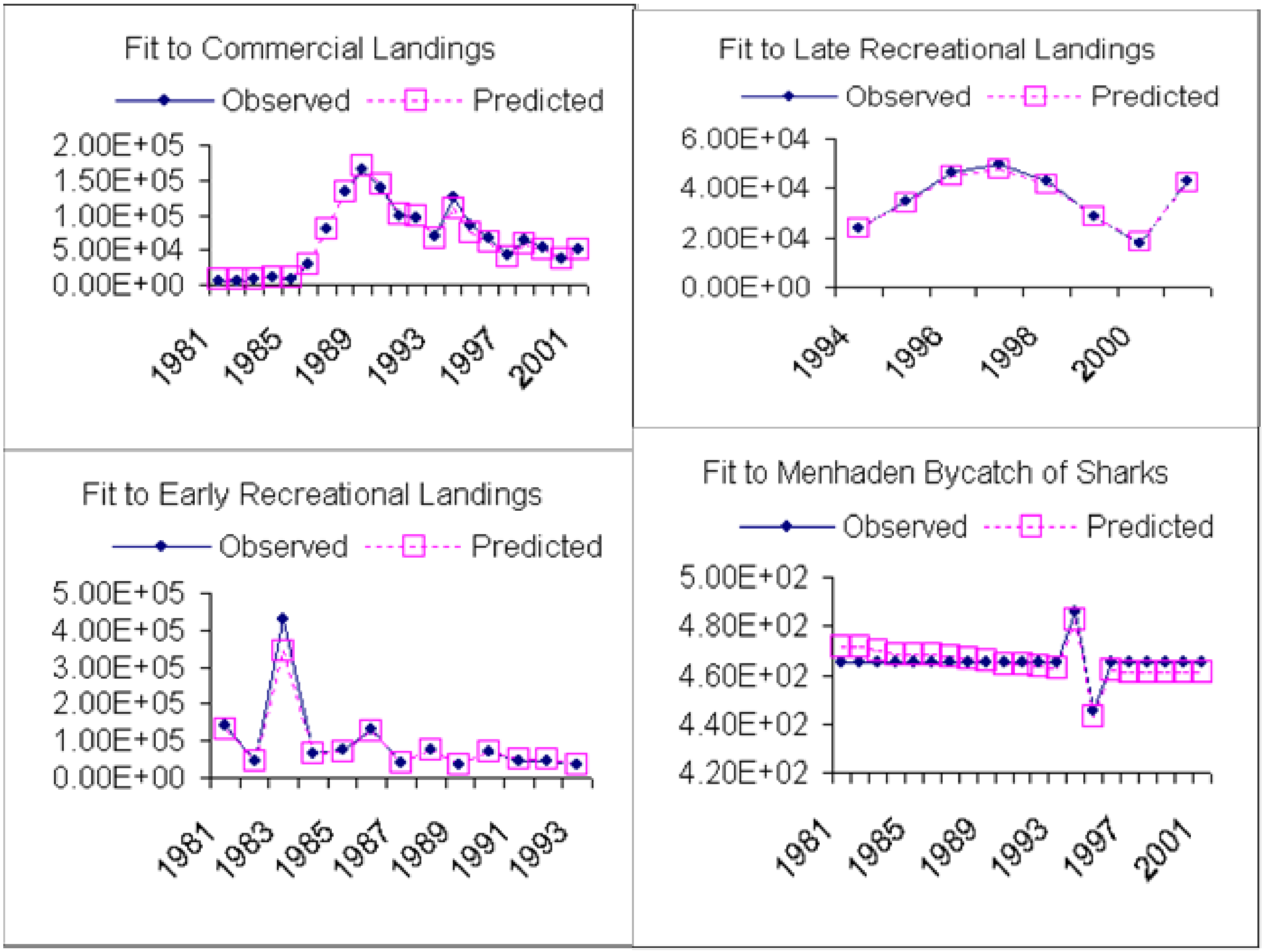
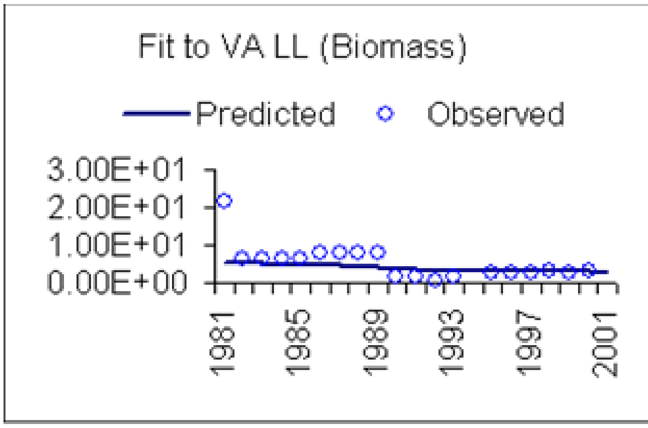
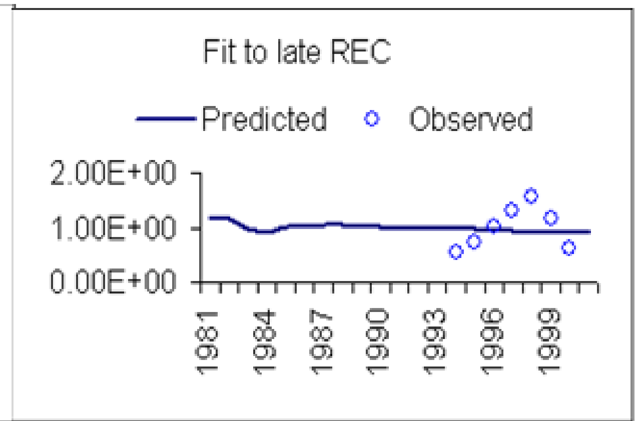
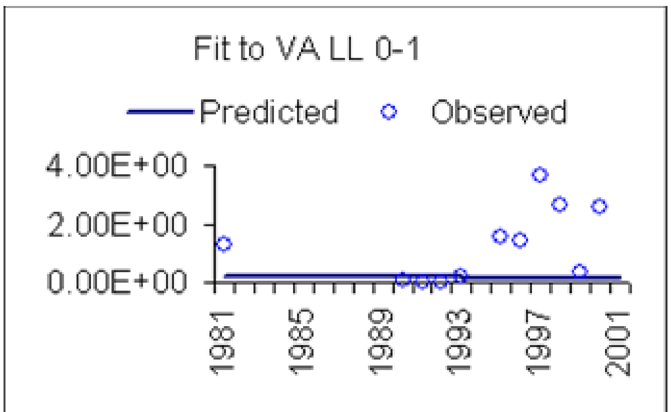
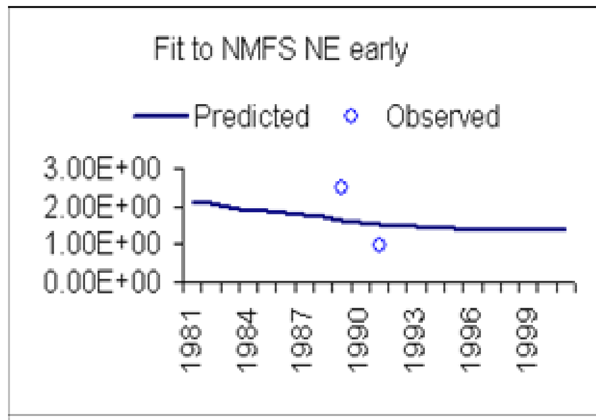


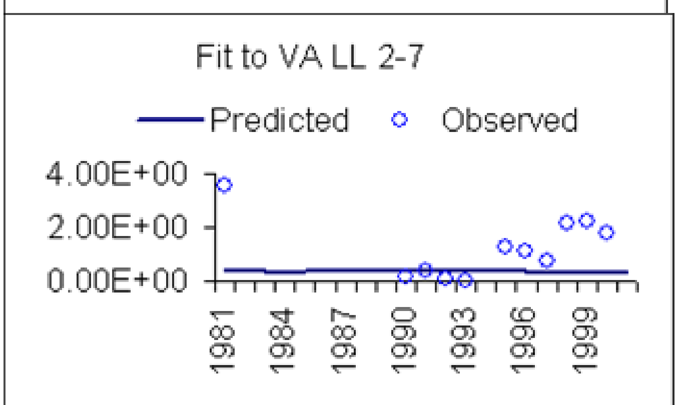
Figure 63. Fit of Sandbar Baseline ASPM model to catches using all CPUE indices.

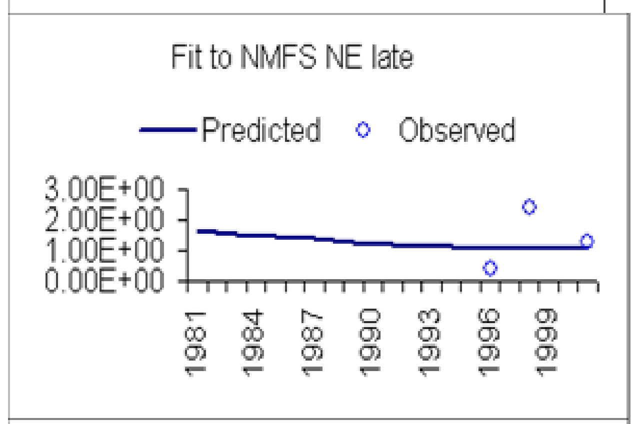

Fit to VA LL (Biomass)
Predicted
Observed
3.00E+01
2.00E+01
1.00E+01
0.00E+00
1981
1985
1989
1993
1997
2001

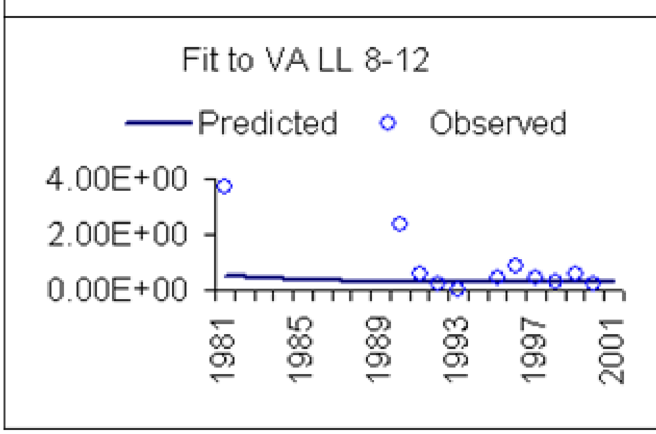

Fit to late REC
Predicted
Observed
2.00E+00
1.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999

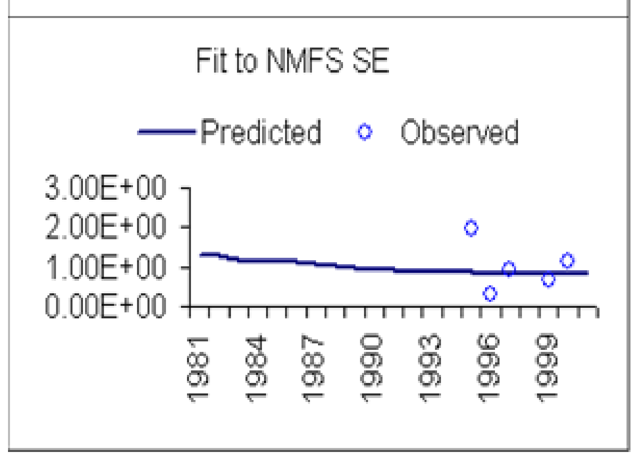

Fit to VA LL 0-1
Predicted
Observed
4.00E+00
2.00E+00
0.00E+00
1981
1985
1989
1993
1997
2001


Fit to NMFS NE early
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999


Fit to VA LL 2-7
Predicted
Observed
4.00E+00
2.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999


Fit to NMFS NE late
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999


Fit to VA LL 8-12
Predicted
Observed
4.00E+00
2.00E+00
0.00E+00
1981
1985
1989
1993
1997
2001


Fit to NMFS SE
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999

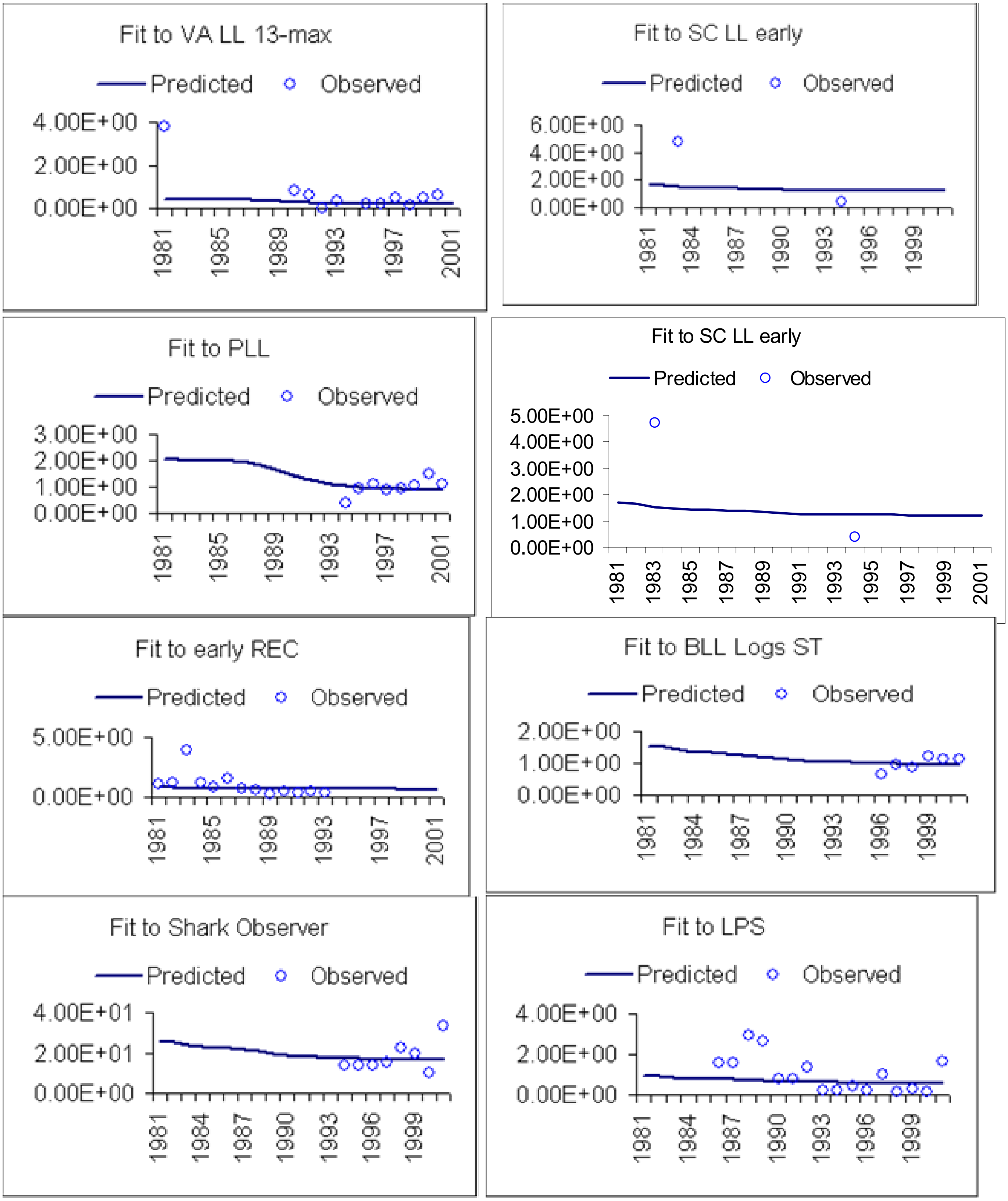


Figure 64. Fit to CPUE indices for Sandbar Baseline ASPM model using all indices.

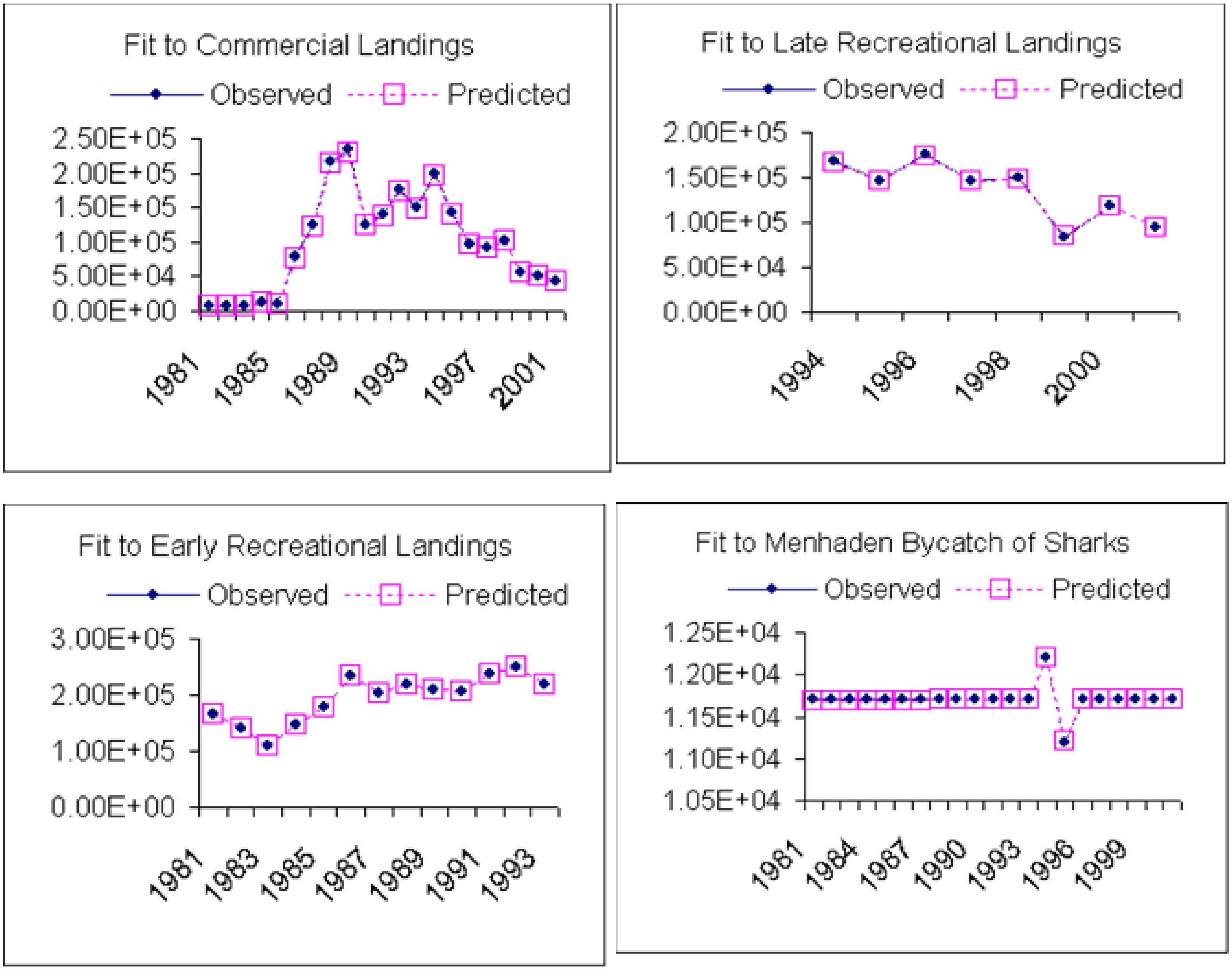
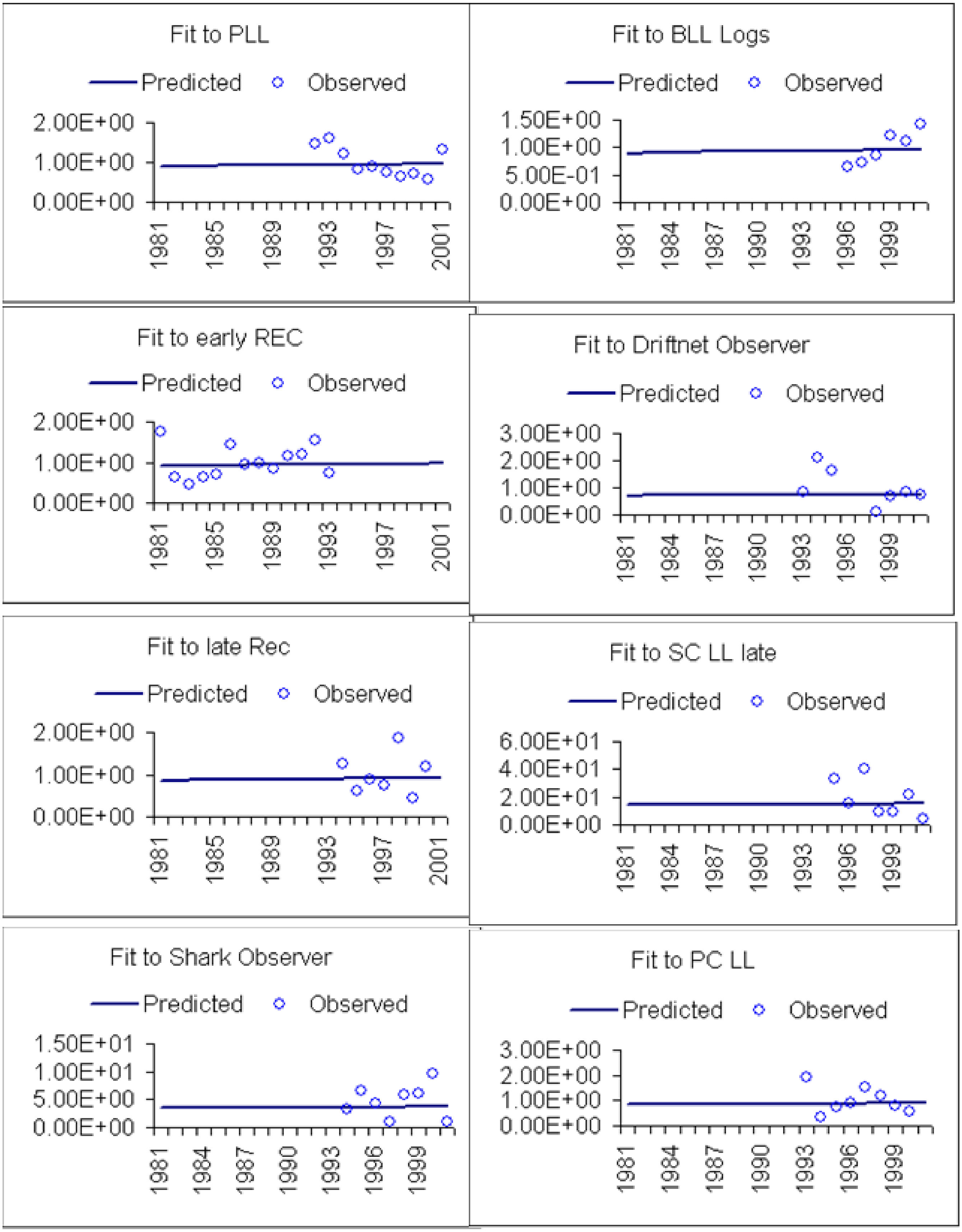


Figure 65. Fit of Blacktip Baseline ASPM model to catches using all CPUE indices.



Fit to PLL
Predicted
Observed
2.00E+00
1.00E+00
0.00E+00
1981
1985
1989
1993
1997
2001
Fit to BLL Logs
Predicted
Observed
1.50E+00
1.00E+00
5.00E-01
0.00E+00
1981
1984
1987
1990
1993
1996
1999
Fit to early REC
Predicted
Observed
2.00E+00
1.00E+00
0.00E+00
1981
1985
1989
1993
1997
2001
Fit to Driftnet Observer
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999
Fit to late Rec
Predicted
Observed
2.00E+00
1.00E+00
0.00E+00
1981
1985
1989
1993
1997
2001
Fit to SC LL late
Predicted
Observed
6.00E+01
4.00E+01
2.00E+01
0.00E+00
1981
1984
1987
1990
1993
1996
1999
Fit to Shark Observer
Predicted
Observed
1.50E+01
1.00E+01
5.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999
Fit to PC LL
Predicted
Observed
3.00E+00
2.00E+00
1.00E+00
0.00E+00
1981
1984
1987
1990
1993
1996
1999

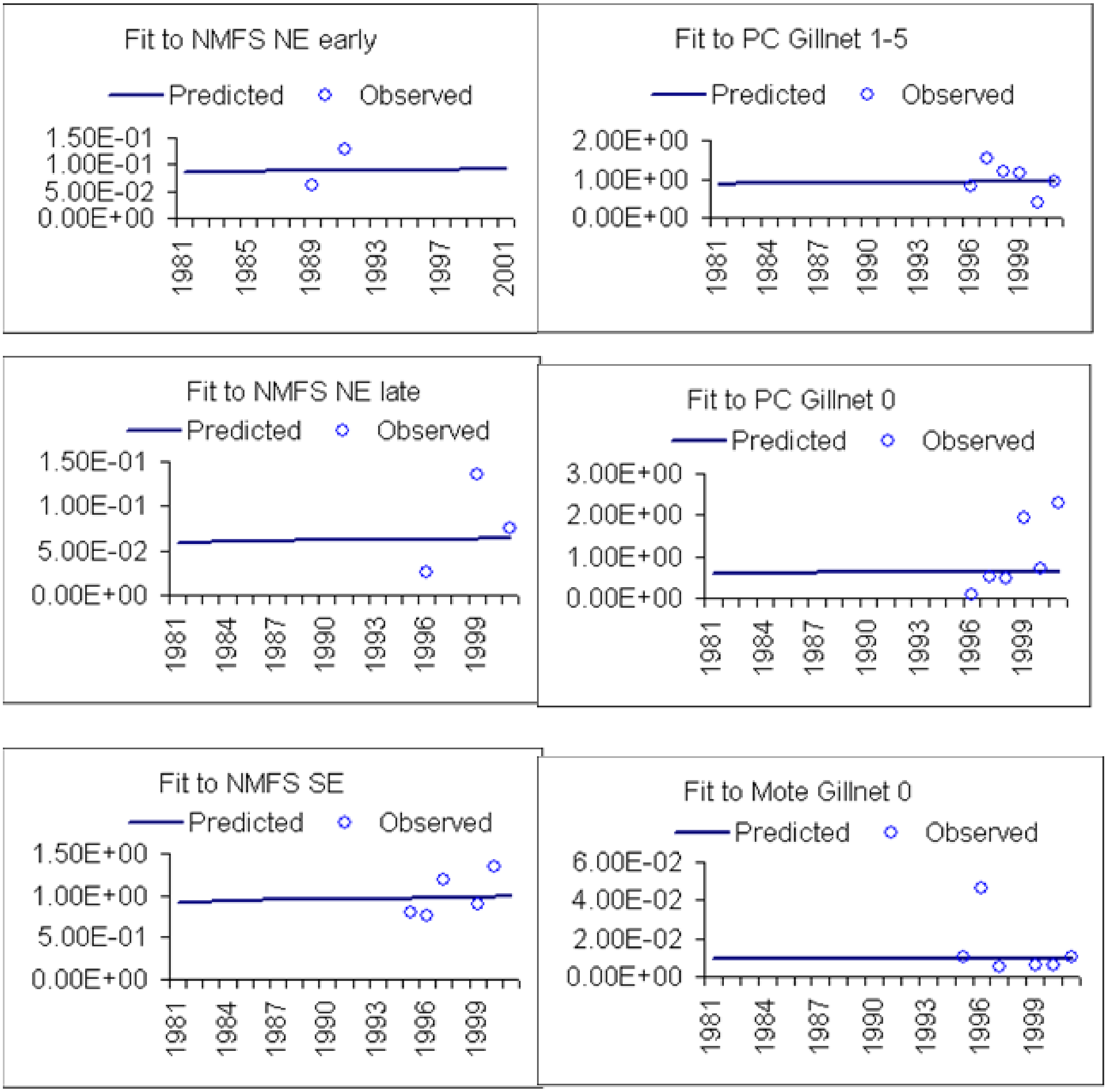


Figure 66. Fit to CPUE indices for Blacktip Baseline ASPM model when using all CPUE indices.

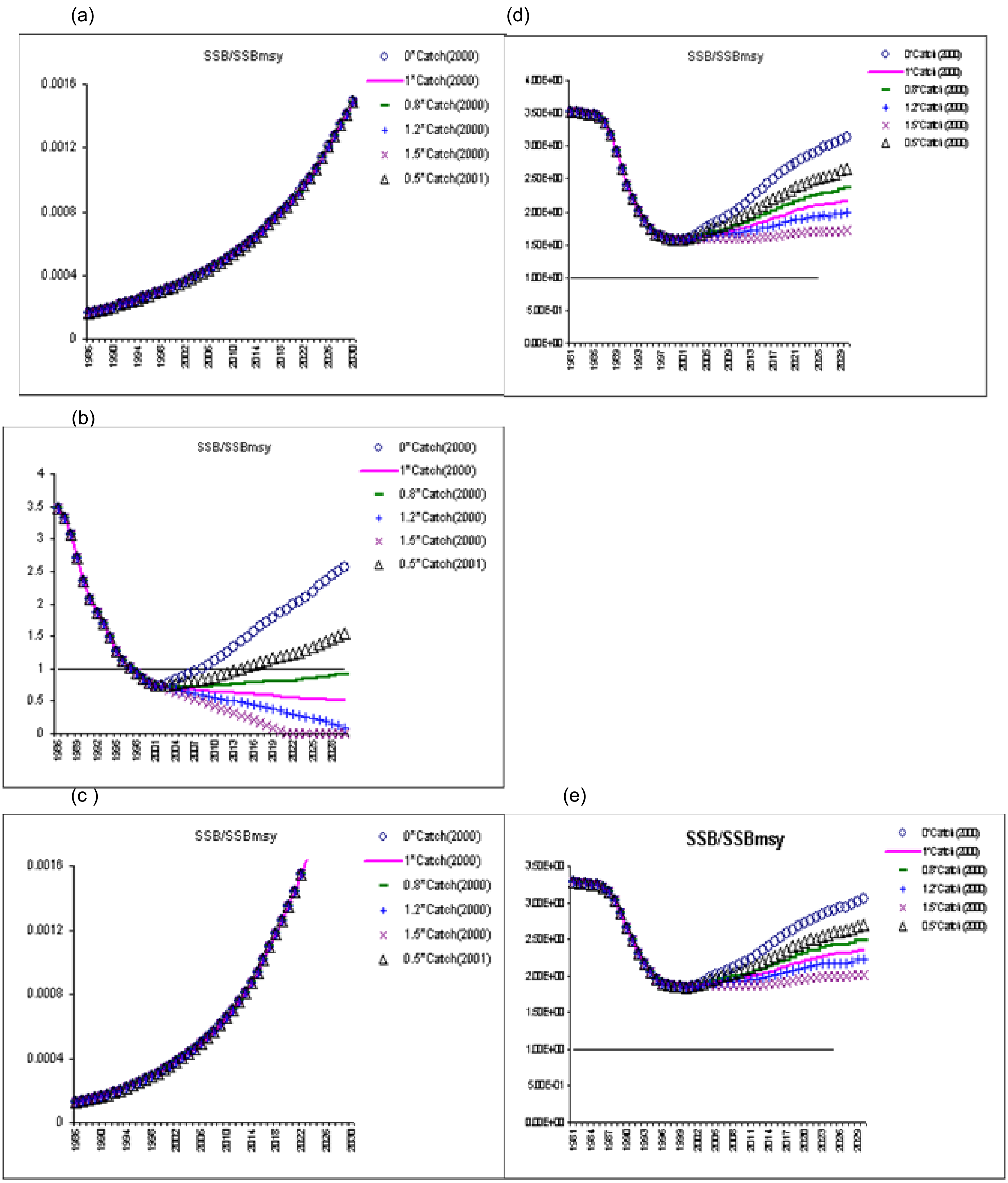


Figure 67. Projections of SSB/SSB_{msy} for 6 catch scenarios for Sandbar Shark models (a) SB_U_all; (b) SB_U_FD; (c) SB_U_FI; (d) SB_B_all; (e) SB_B_FI. ‘0’ = 0*Catch(2000); solid line = 1*Catch(2000); ‘-‘ = 0.8*Catch(2000); triangle = 0.5*Catch(2000); ‘+’ = 1.2*Catch(2000); ‘x’ = 1.5*Catch(2000).

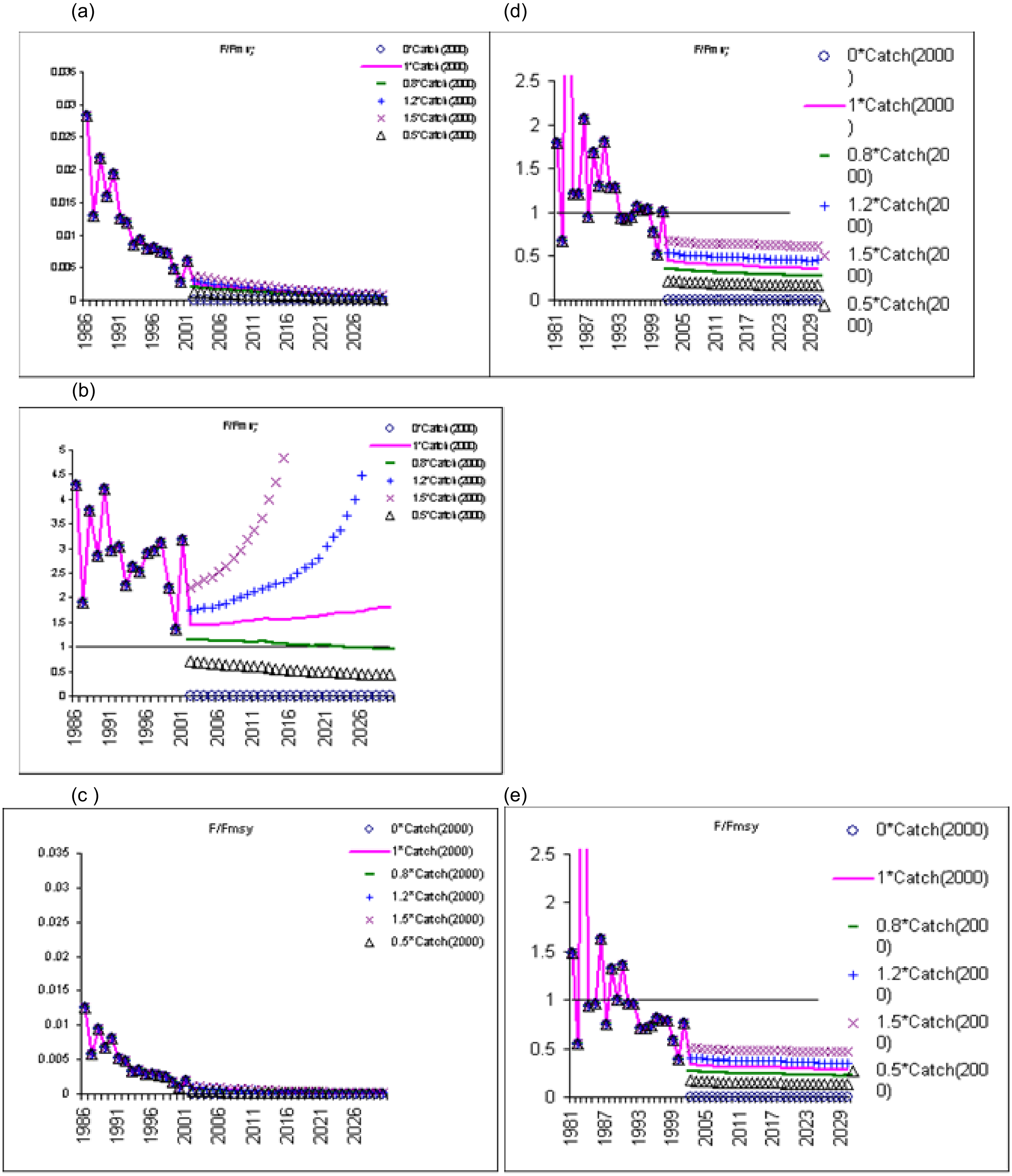


Figure 68. Projections of F/F_{msy} for 6 catch scenarios for Sandbar Shark models (a) SB_U_all; (b) SB_U_FD; (c) SB_U_FI; (d) SB_B_all; (e) SB_B_FI.

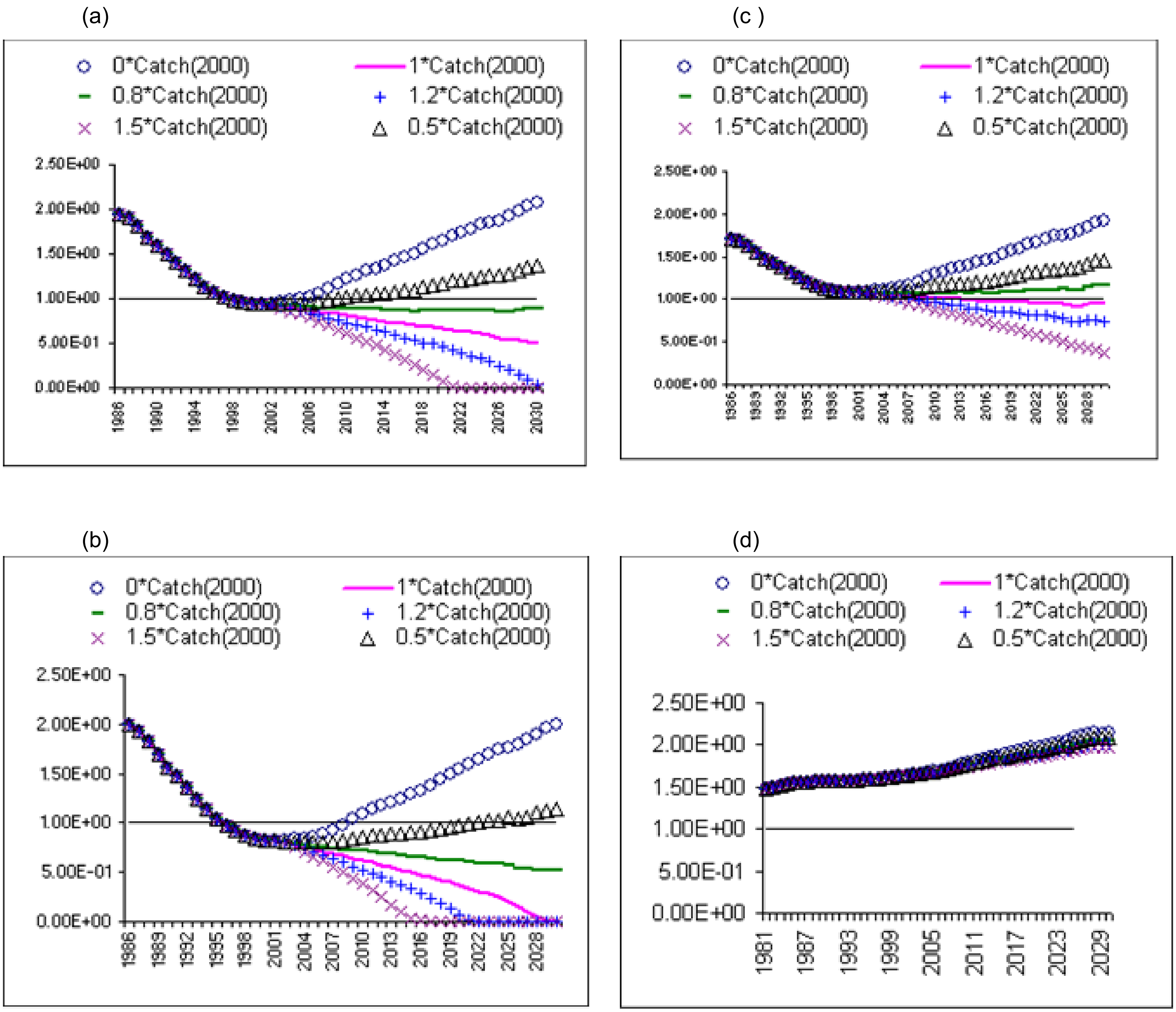


Figure 69. Projections of SSB/SSB_{msy} for 6 catch scenarios for Blacktip Shark models (a) BT_U_all; (b) BT_U_FD; (c) BT_U_FI; (d) BT_B_all.

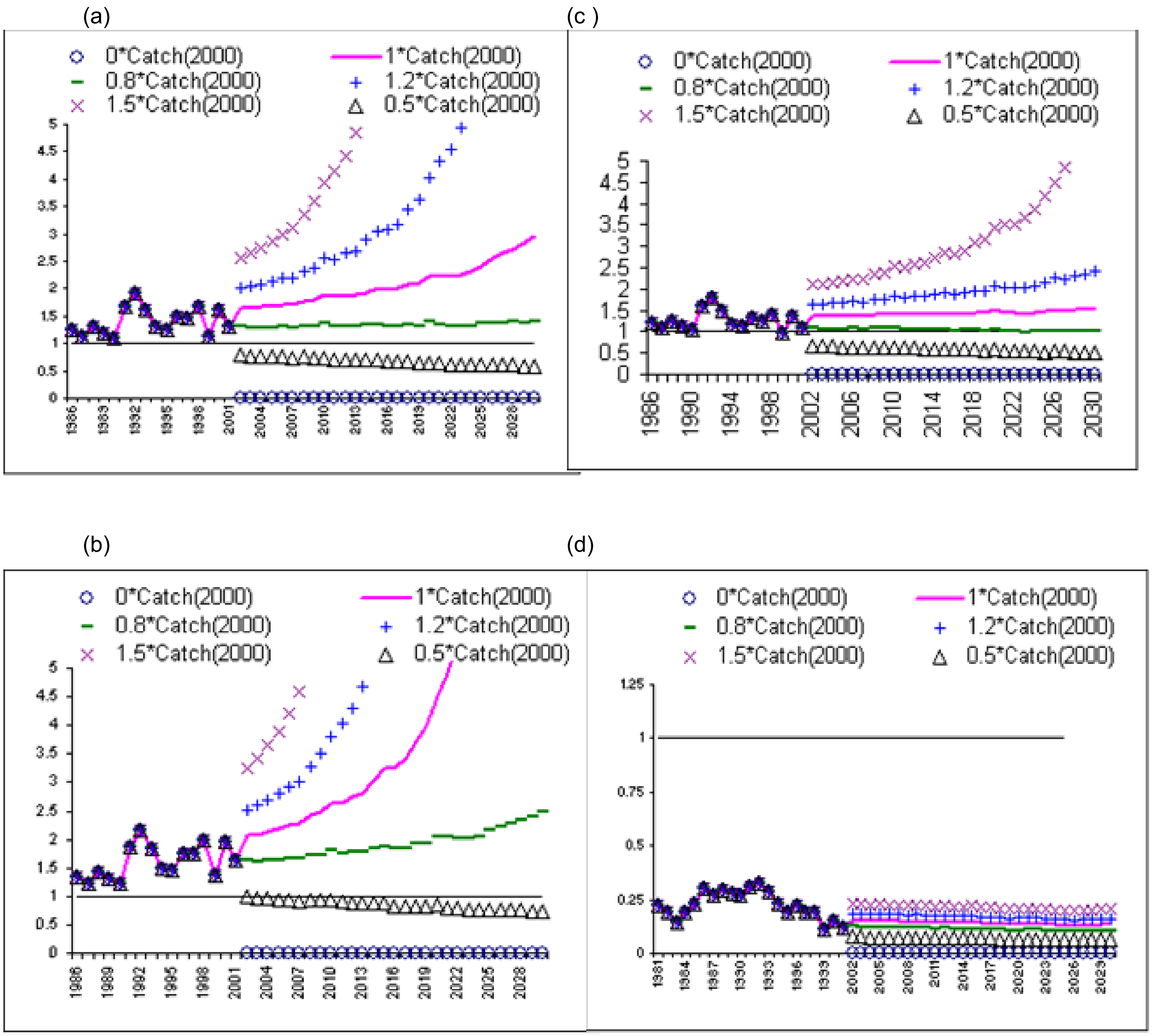


Figure 70. Projections of F/F_{msy} for 6 catch scenarios for Blacktip Shark models (a) BT_U_all; (b) BT_U_FD; (c) BT_U_FI; (d) BT_B_all.

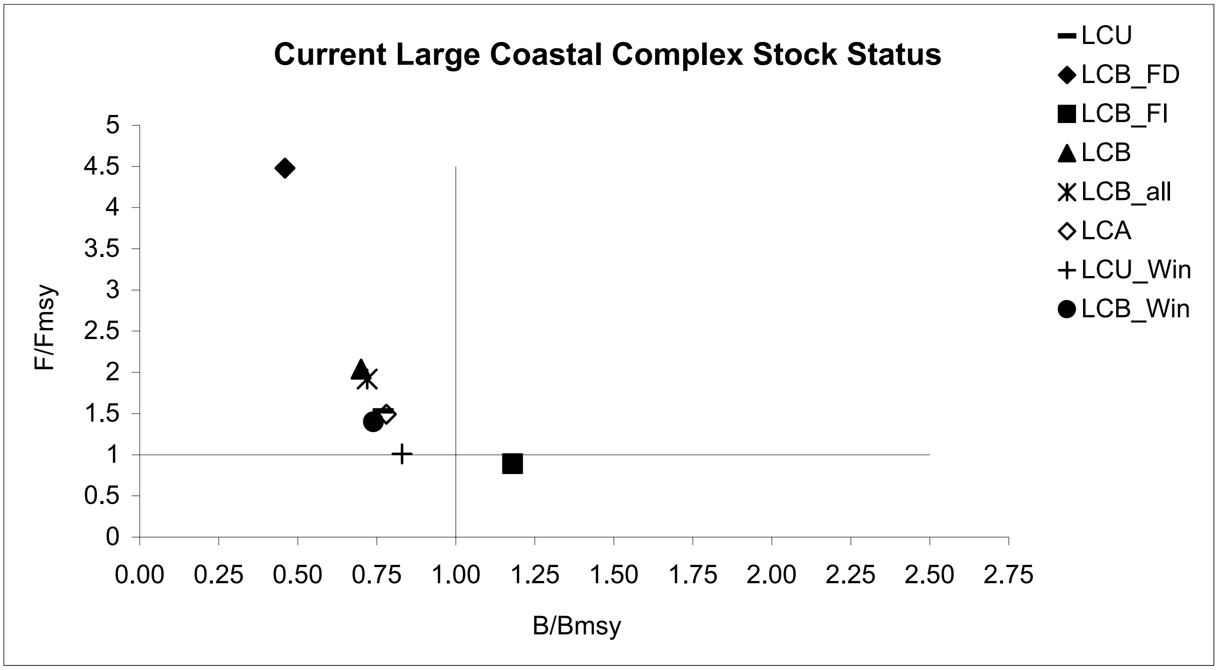
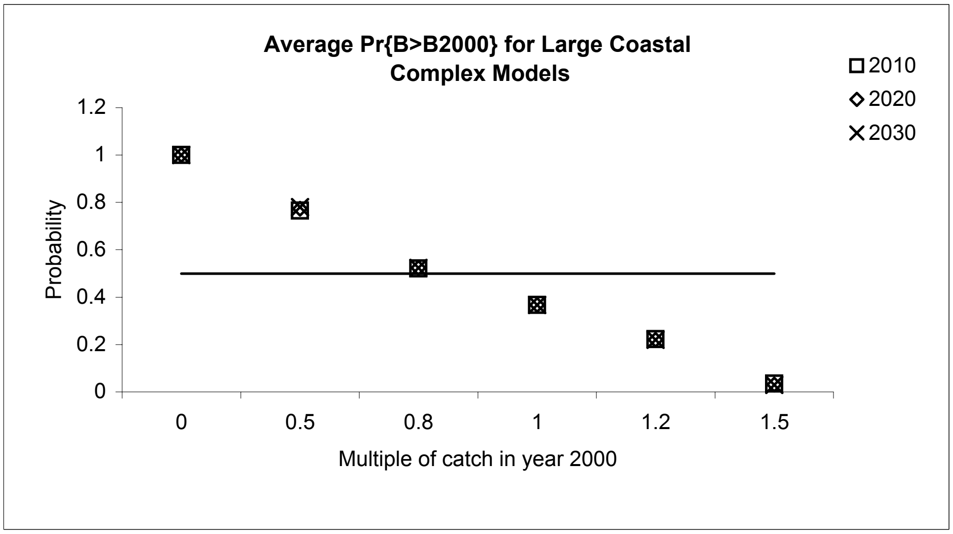


Figure 71. Phase plot for the large coastal shark complex showing values of B_{2001}/B_{msy} and F_{2001}/F_{msy} obtained in several scenarios using multiple stock assessment models. Results from the Bayesian SPM using the SIR algorithm include: LCU (updated scenario), LCB_FD (baseline scenario with only fishery-dependent indices), LCB_FI (baseline with only fishery-independent indices), LCB (baseline scenario), LCB_all (baseline with all available indices), and LCA (alternative catch scenario). Results from the SSSPM using WinBUGS include: LCU_Win (updated scenario) and LCB_Win (baseline scenario). Several control rules are illustrated: the solid horizontal line indicates the Maximum Fishing Mortality Threshold; the solid vertical line indicates the target biomass.

A



B

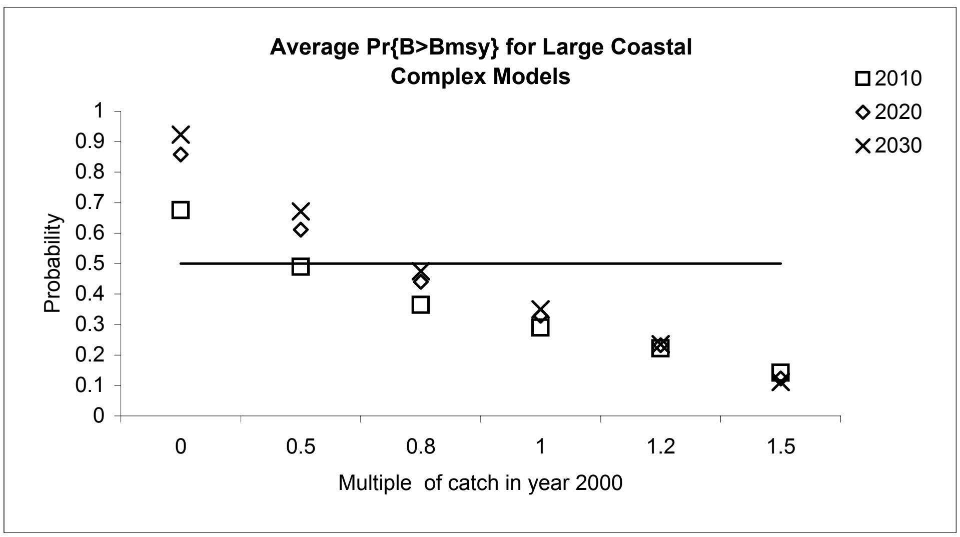


Figure 72. Summary plots for the large coastal shark complex of the mean probability that A) $B>B_{2000}$ or B) $B>B_{msy}$ obtained in six main scenarios using the Bayesian SPM with the SIR algorithm. The scenarios include: LCU (updated scenario), LCB_FD (baseline scenario with only fishery-dependent indices), LCB_FI (baseline with only fishery-independent indices), LCB (baseline scenario), LCB_all (baseline with all available indices),and LCA (alternative catch scenario). Mean probabilities are shown for three different time horizons (10, 20, and 30 years) under each of six different harvest policies (expressed as a multiple of the 2000 catch). The solid horizontal line denotes 50% probability.

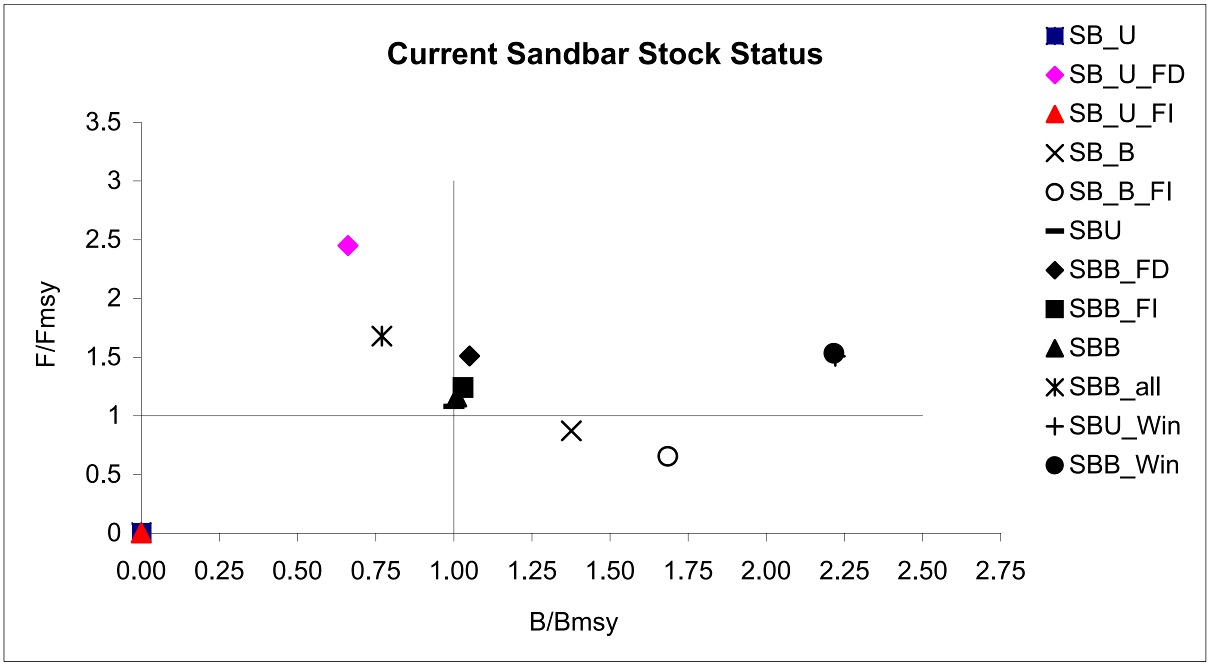
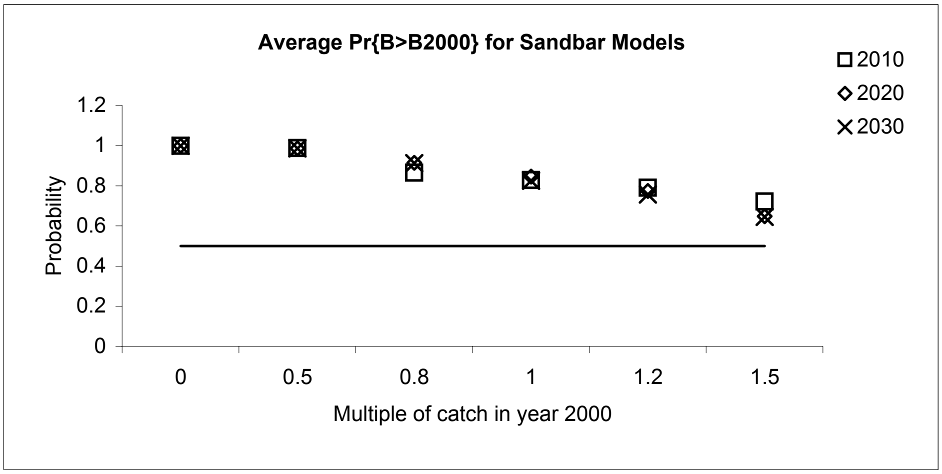


Figure 73. Phase plot for sandbar shark showing values of B_{2001}/B_{msy} andF_{2001}/F_{msy} obtained in several scenarios using multiple stock assessment models. Results from the ASPM model include: SB_U (updated scenario), SB_U_FD (updated scenario with only fishery-dependent indices), SB_U_FI (updated with only fishery-independent indices), SB_B (baseline scenario), and SB_B_FI (baseline with only fishery-independent indices). Results from the Bayesian SPM using the SIR algorithm include: SBU (updated scenario), SBB_FD (baseline scenario with only fishery-dependent indices), SBB_FI (baseline with only fishery-independent indices), SBB (baseline scenario), and SBB_all (baseline with all available indices). Results from the SSLRSG using WinBUGS include: SBU_Win (updated scenario) and SBB_Win (baseline scenario). Several control rules are illustrated: the solid horizontal line indicates the Maximum Fishing Mortality Threshold; the solid vertical line indicates the target biomass.

A



B

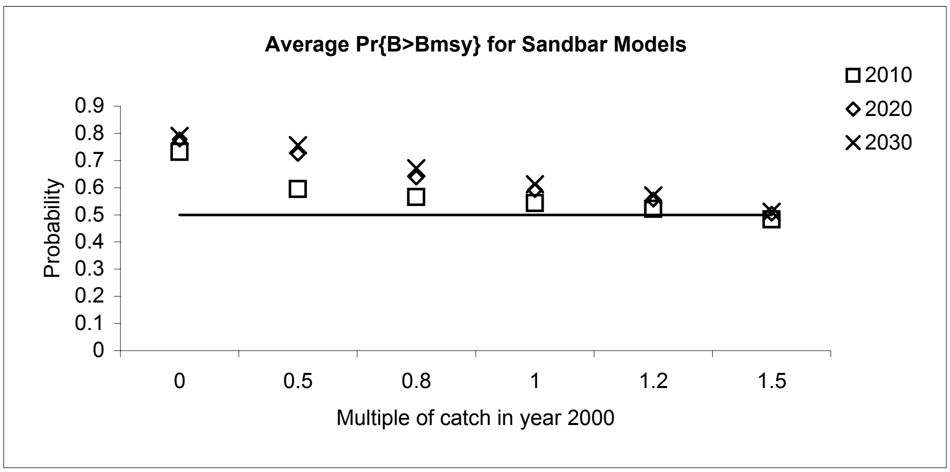


Figure 74. Summary plots for sandbar shark of the mean probability that A) $B>B_{2000}$ or B) $B>B_{msy}$ obtained in five main scenarios using the Bayesian SPM with the SIR algorithm and five main scenarios using the ASPM model. The scenarios for the Bayesian SPM include: SBU (updated scenario), SBB_FD (baseline scenario with only fishery-dependent indices), SBB_FI (baseline with only fishery-independent indices), SBB (baseline scenario), and SBB_all (baseline with all available indices). For the ASPM, scenarios include: SB_U (updated scenario), SB_U_FD (updated scenario with only fishery-dependent indices), SB_U_FI (updated with only fishery-independent indices), SB_B (baseline scenario), and SB_B_FI (baseline with only fishery-independent indices). Mean probabilities are shown for three different time horizons (10, 20, and 30 years) under each of six different harvest policies (expressed as a multiple of the 2000 catch). The solid horizontal line denotes 50% probability.

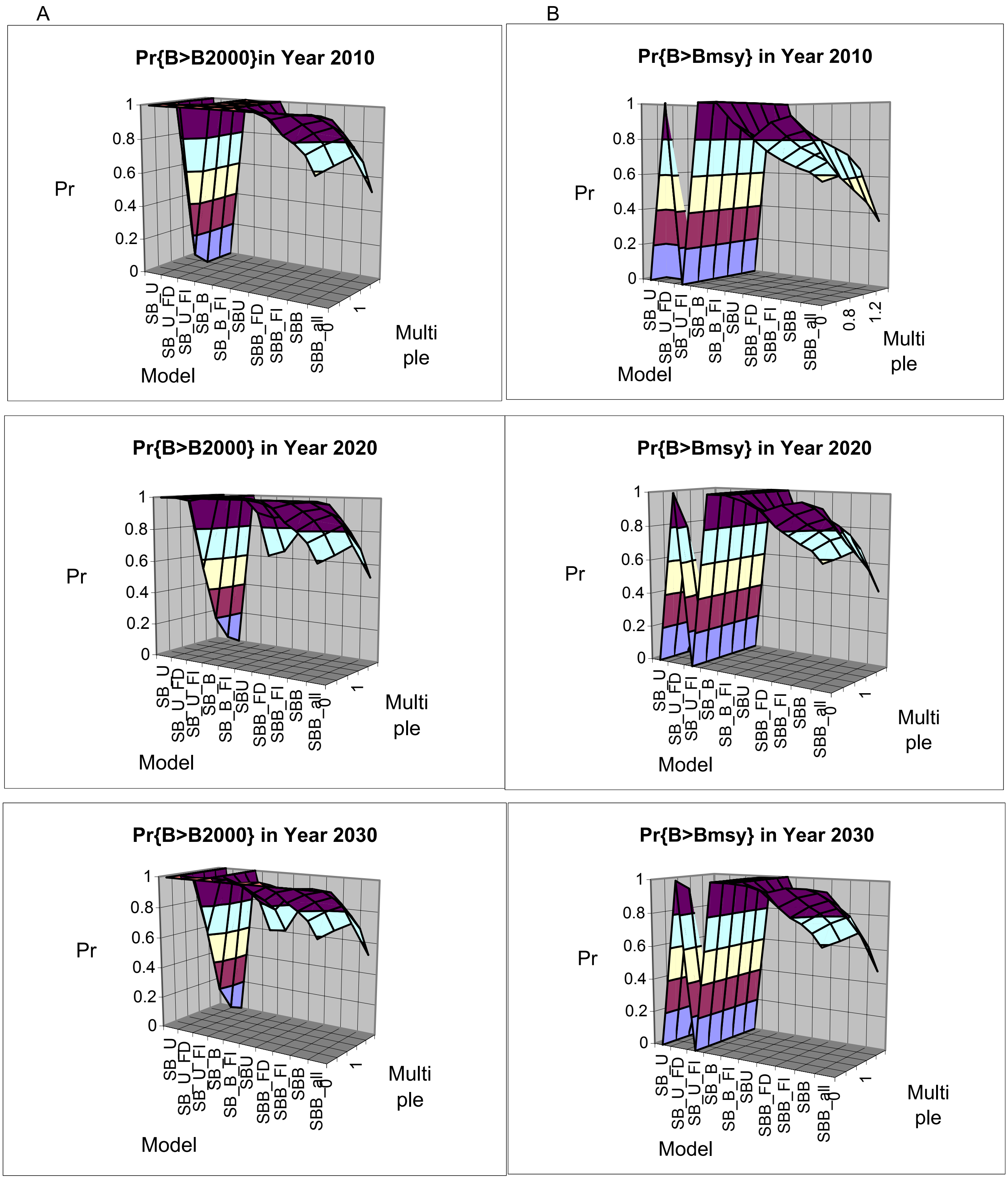


Figure 75. Surface plots for sandbar shark of the mean probability that A) $B>B_{2000}$ and B) $B>B_{msy}$ obtained in five main scenarios using the Bayesian SPM with the SIR algorithm and five main scenarios using the ASPM model. The scenarios for the Bayesian SPM include: SBU (updated scenario), SBB_FD (baseline scenario with only fishery-dependent indices), SBB_FI (baseline with only fishery-independent indices), SBB (baseline scenario), and SBB_all (baseline with all available indices). For the ASPM, scenarios include: SB_U (updated scenario), SB_U_FD (updated scenario with only fishery-dependent indices), SB_U_FI (updated with only fishery-independent indices), SB_B (baseline scenario), and SB_B_FI (baseline with only fishery-independent indices). Mean probabilities are shown for three different time horizons (10, 20, and 30 years) under each of six different harvest policies (expressed as a multiple of the 2000 catch).

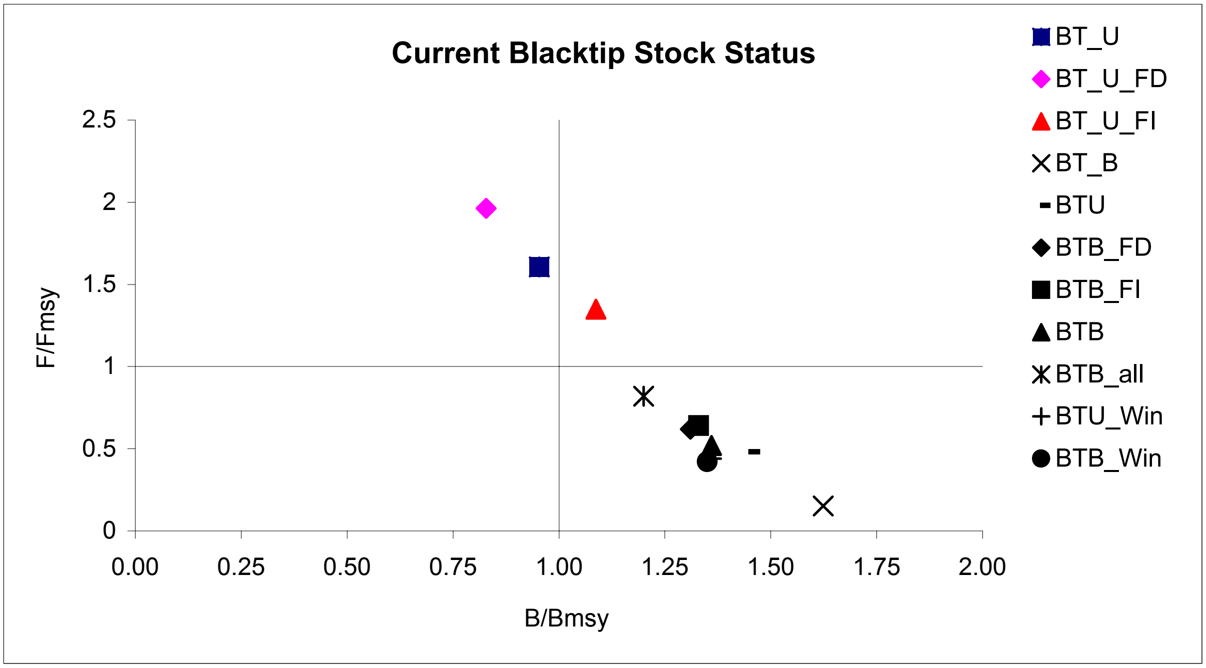
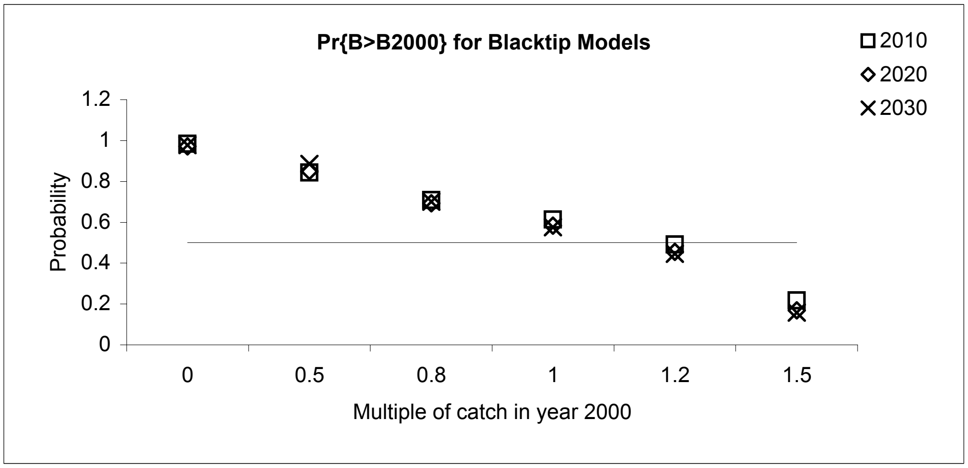


Figure 76. Phase plot for blacktip shark showing values of B_{2001}/B_{msy} and F_{2001}/F_{msy} obtained in several scenarios using multiple stock assessment models. Results from the ASPM model include: BT_U (updated scenario), BT_U_FD (updated scenario with only fishery-dependent indices), BT_U_FI (updated with only fishery-independent indices), and BT_B (baseline scenario) Results from the Bayesian SPM using the SIR algorithm include: BTU (updated scenario), BTB_FD (baseline scenario with only fishery-dependent indices), BTB_FI (baseline with only fishery-independent indices), BTB (baseline scenario), and BTB_all (baseline with all available indices). Results from the SSSPM using WinBUGS include: BTU_Win (updated scenario) and BTB_Win (baseline scenario). Several control rules are illustrated: the solid horizontal line indicates the Maximum Fishing Mortality Threshold; the solid vertical line indicates the target biomass.

A



B

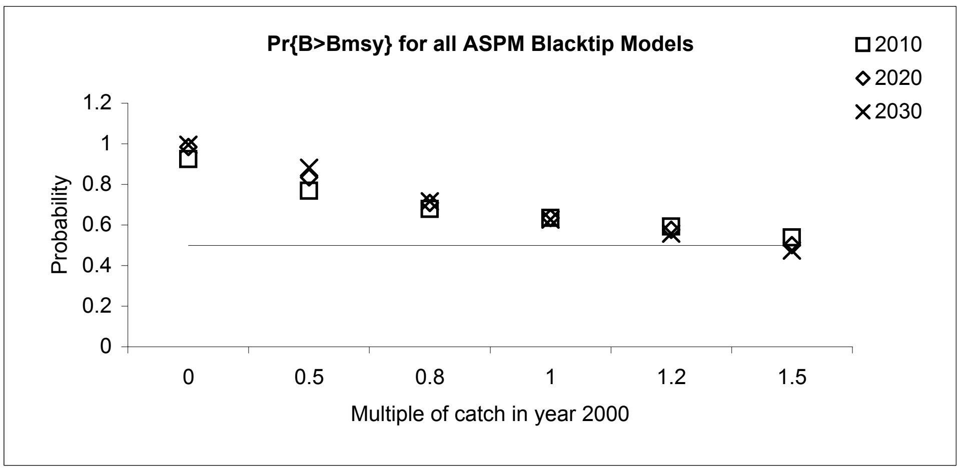


Figure 77. Summary plots for blacktip shark of the mean probability that A) $B>B_{2000}$ or B) $B>B_{msy}$ obtained in five main scenarios using the Bayesian SPM with the SIR algorithm and four main scenarios using the ASPM model. The scenarios for the Bayesian SPM include: BTU (updated scenario), BTB_FD (baseline scenario with only fishery-dependent indices), BTB_FI (baseline with only fishery-independent indices), BTB (baseline scenario), and BTB_all (baseline with all available indices). For the ASPM, scenarios include: BT_U (updated scenario), BT_U_FD (updated scenario with only fishery-dependent indices), BT_U_FI (updated with only fishery-independent indices), and BT_B (baseline scenario). Mean probabilities are shown for three different time horizons (10, 20, and 30 years) under each of six different harvest policies (expressed as a multiple of the 2000 catch). The solid horizontal line denotes 50% probability.

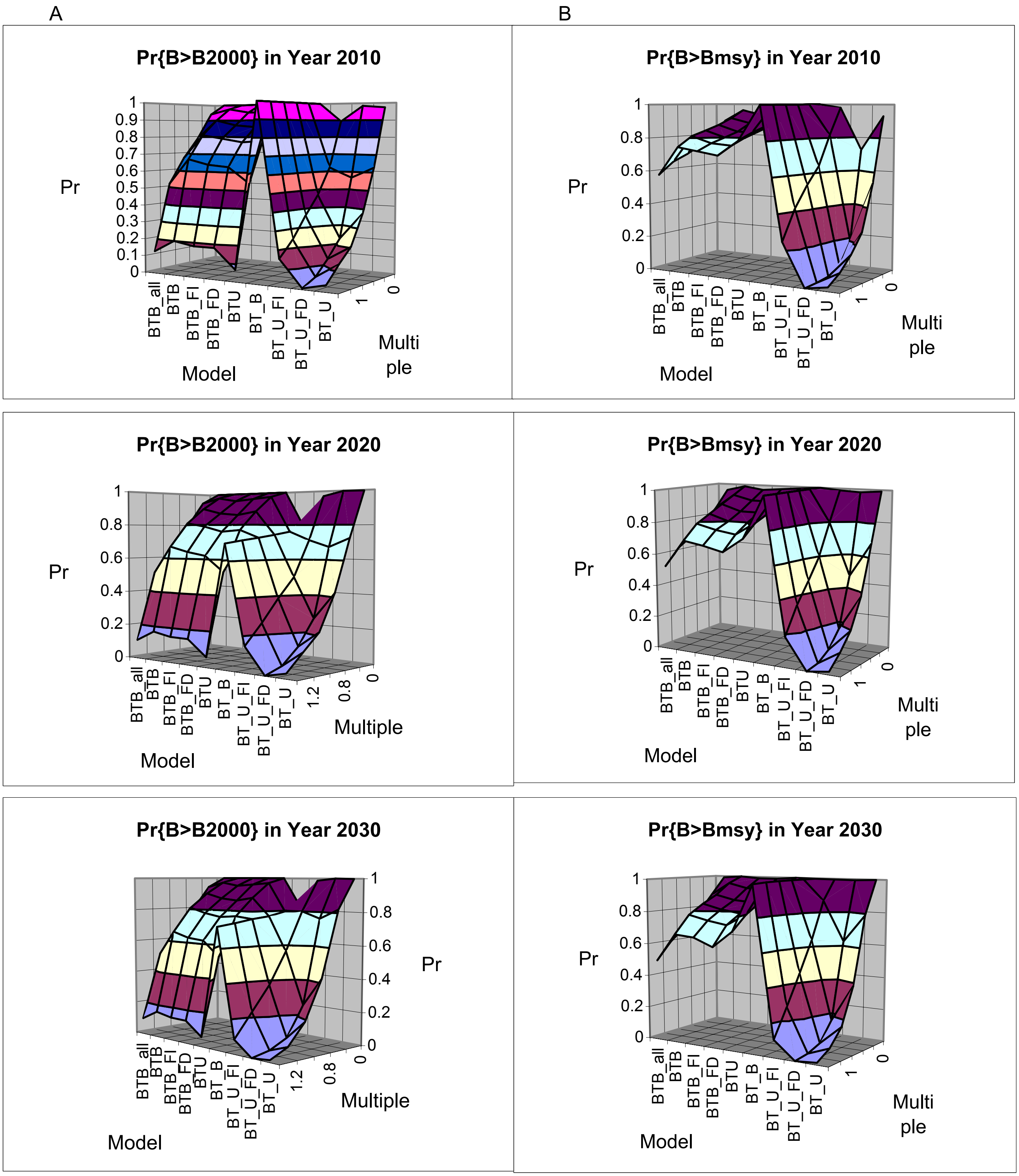


Figure 78. Surface plots for blacktip shark of the mean probability that A) $B>B_{2000}$ and B) $B>B_{msy}$, obtained in five main scenarios using the Bayesian SPM with the SIR algorithm and four main scenarios using the ASPM model. The scenarios for the Bayesian SPM include: BTU (updated scenario), BTB_FD (baseline scenario with only fishery-dependent indices), BTB_FI (baseline with only fishery-independent indices), BTB (baseline scenario), and BTB_all (baseline with all available indices). For the ASPM, scenarios include: BT_U (updated scenario), BT_U_FD (updated scenario with only fishery-dependent indices), BT_U_FI (updated with only fishery-independent indices), and BT_B (baseline scenario). Mean probabilities are shown for three different time horizons (10, 20, and 30 years) under each of six different harvest policies (expressed as a multiple of the 2000 catch).

Appendix 1. CPUE Series for Large Coastal Sharks

Available CPUE series for the large coastal shark complex, sandbar, and blacktip shark. The index is the estimated mean CPUE and the CV is the estimated precision of the mean value. Type refers to whether the index is fishery-independent (F-I) or fishery-dependent (F-D), recreational (R) or commercial (C). Observations with a CV of 1.0 are nominal data for which no measure of the precision of the estimate was available. The column "Standardized?" refers to whether the series was standardized or not through GLM procedures. The series used in the surplus production and simplified delay-difference models for the large coastal shark complex, sandbar, and blacktip shark are listed first; age-specific series used in the age-structured analyses for sandbar and blacktip shark are listed next. The age classes that each index is believed to have sampled are listed under the series name.

Series name	Type	Year	Index	CV	Standardized?
Large coastal shark complex					
Brannon	F-D (C)	1986	162	1	No
		1987	332.29	1	
		1988	282.56	1	
		1989	205.41	1	
		1990	245.07	1	
		1991	251.44	1	
Hudson	F-D (C)	1985	0.22	1	No
		1986	0.10	1	
		1987	0.12	1	
		1988	0.10	1	
		1989	0.05	1	
		1990	0.02	1	
		1991	0.02	1	
Crooke LL	F-D (C)	1975	0.11	1	No
		1976	0.08	1	
		1977	0.13	1	
		1978	0.25	1	
		1979	0.12	1	
		1980	0.16	1	
		1981	0.13	1	
		1982	0.13	1	
		1983	0.14	1	
		1984	0.12	1	
		1985	0.14	1	
		1986	0.11	1	
		1987	0.08	1	
		1988	0.08	1	
		1989	0.09	1	
Shark observer	F-D (C)	1994	23.702	1.100	No
		1995	32.618	1.041	
		1996	29.176	1.334	
		1997	28.711	1.079	
		1998	50.340	0.931	
		1999	51.286	1.228	
		2000	42.693	0.933	

		2001	53.396	1.090	
Jax	F-D (R)	1979	0.59	1	No
		1984	0.71	1	
		1990	0.16	1	
NC #	F-D (C)	1988	999.10	0.422	No
		1989	1637.36	0.232	
SC LL early	F-I	1983	6.220	1	No
		1994	2.440	1	
SC LL recent	F-I	1995	57.862	0.359	Yes
		1996	49.279	0.257	
		1997	97.346	0.183	
		1998	60.739	0.194	
		1999	92.178	0.148	
		2000	79.165	0.169	
		2001	61.831	0.216	
Port Salerno	F-D (R)	1976	0.18	1	No
		1977	0.81	1	
		1979	0.89	1	
		1980	0.82	1	
		1981	0.39	1	
		1982	0.50	1	
		1983	0.12	1	
		1984	0.10	1	
		1985	0.15	1	
		1986	0.50	1	
		1987	0.32	1	
		1988	0.20	1	
		1989	0.12	1	
		1990	0.20	1	
Tampa Bay	F-D (R)	1985	0.16	1	No
		1986	0.09	1	
		1987	0.03	1	
		1988	0.14	1	
		1989	0.06	1	
		1990	0.05	1	
Virginia LL	F-I	1974	2.818	0.289	No
		1975	5.373	0.298	
		1976	9.007	0.351	
		1977	1.817	0.382	
		1980	4.788	0.180	
		1981	4.280	0.164	
		1983	1.863	0.151	
		1984	2.217	0.272	
		1986	1.109	0.219	
		1987	1.863	0.522	
		1988	1.986	0.237	
		1989	1.678	0.399	
		1990	0.647	0.234	
		1991	0.770	0.250	
		1992	0.493	0.328	
		1993	0.801	0.455	
		1995	1.278	0.267	
		1996	1.647	0.224	
		1997	1.812	0.166	
		1998	2.244	0.170	
		1999	2.435	0.231	

		2000	2.223	0.178	
LPS	F-D (R)	1986	52.91	0.142	Yes
		1987	40.42	0.175	
		1988	32.50	0.210	
		1989	65.42	0.128	
		1990	24.40	0.241	
		1991	46.45	0.148	
		1992	20.64	0.289	
		1993	13.53	0.465	
		1994	4.510	1.136	
		1995	18.22	0.366	
		1996	25.91	0.356	
		1997	16.65	0.469	
Charterboat	F-D (R)	1989	411.44	0.125	Yes
		1990	370.33	0.121	
		1991	387.92	0.118	
		1992	300.56	0.125	
		1993	339.37	0.156	
		1994	333.26	0.152	
		1995	372.11	0.122	
PLL	F-D (C)	1986	2.185	0.218	Yes
		1987	1.396	0.109	
		1988	1.726	0.100	
		1989	1.337	0.102	
		1990	1.614	0.093	
		1991	1.375	0.062	
		1992	1.155	0.06	
		1993	1.001	0.063	
		1994	0.635	0.066	
		1995	0.513	0.072	
		1996	0.498	0.081	
		1997	0.427	0.087	
		1998	0.429	0.089	
		1999	0.437	0.091	
		2000	0.673	0.111	
		2001	0.599	0.119	
Early Rec	F-D (R)	1981	1.284	1	No
		1982	1.200	1	
		1983	2.368	1	
		1984	0.993	1	
		1985	0.847	1	
		1986	1.344	1	
		1987	0.919	1	
		1988	0.771	1	
		1989	0.479	1	
		1990	0.631	1	
		1991	0.618	1	
		1992	0.869	1	
		1993	0.677	1	
Late Rec	F-D (R)	1994	0.878	1	No
		1995	0.891	1	
		1996	0.930	1	
		1997	0.956	1	
		1998	1.217	1	
		1999	0.921	1	
		2000	1.208	1	

NMFS LL NE early	F-I	1989	4.061	0.487	No
		1991	2.192	0.708	
NMFS LL NE late	F-I	1996	0.638	1.995	No
		1998	3.301	1.862	
		2001	2.374	2.045	
NMFS LL SE	F-I	1995	1.166	0.968	Yes
		1996	0.492	2.135	
		1997	0.883	0.985	
		1999	0.611	1.220	
		2000	1.320	0.546	
		2001	1.529	0.582	
Driftnet observer	F-D (C)	1993	0.894	1.699	Yes
		1994	2.494	0.635	
		1995	1.826	1.593	
		1998	0.537	1.862	
		1999	0.535	0.387	
		2000	0.379	0.393	
		2001	0.335	0.348	
BLL Logs ST	F-D (C)	1996	0.650	0.188	Yes
		1997	0.954	0.104	
		1998	0.854	0.100	
		1999	1.253	0.093	
		2000	1.178	0.105	
		2001	1.112	0.103	
Sandbar shark					
Virginia LL	F-I	1974	2.585	0.314	No
		1975	3.473	0.313	
		1976	8.321	0.380	
		1977	2.419	0.537	
		1980	4.430	0.176	
		1981	5.457	0.165	
		1983	1.863	0.274	
		1984	1.415	0.604	
		1987	1.373	0.546	
		1988	2.235	0.501	
		1989	2.509	0.433	
		1990	0.532	0.379	
		1991	0.769	0.347	
		1992	0.184	0.432	
		1993	1.004	0.584	
		1995	1.623	0.295	
		1996	1.887	0.298	
		1997	2.106	0.204	
		1998	2.596	0.200	
		1999	1.721	0.328	
		2000	2.275	0.226	
		2000	2.223	0.178	
PLL	F-D (C)	1994	0.416	0.302	Yes
		1995	0.923	0.108	
		1996	1.126	0.110	
		1997	0.906	0.119	
		1998	0.961	0.129	
		1999	1.048	0.128	
		2000	1.486	0.164	
		2001	1.134	0.183	

Early Rec	F-D (R)	1981	1.024	1	No
		1982	1.213	1	
		1983	3.967	1	
		1984	1.244	1	
		1985	0.847	1	
		1986	1.574	1	
		1987	0.678	1	
		1988	0.544	1	
		1989	0.217	1	
		1990	0.517	1	
		1991	0.372	1	
		1992	0.431	1	
		1993	0.373	1	
Late Rec	F-D (R)	1994	0.559	1	No
		1995	0.745	1	
		1996	1.017	1	
		1997	1.295	1	
		1998	1.578	1	
		1999	1.178	1	
		2000	0.628	1	
NMFS LL NE early	F-I	1989	2.514	0.395	No
		1991	0.982	0.458	
NMFS LL NE late	F-I	1996	0.399	2.952	No
		1998	2.395	2.418	
		2001	1.240	2.739	
NMFS LL SE	F-I	1995	1.971	0.952	Yes
		1996	0.299	5.691	
		1997	0.939	1.354	
		1999	0.668	2.747	
		2000	1.123	1.165	
SC LL early	F-I	1983	4.730	1	No
		1994	0.410	1	
SC LL late	F-I	1995	14.522	1.049	Yes
		1996	30.581	0.446	
		1997	20.399	0.576	
		1998	23.811	0.377	
		1999	80.817	0.207	
		2000	21.131	0.396	
		2001	30.830	0.344	
BLL Logs ST	F-D (C)	1996	0.664	0.195	Yes
		1997	0.955	0.154	
		1998	0.881	0.148	
		1999	1.233	0.138	
		2000	1.152	0.154	
		2001	1.114	0.148	
Shark Observer	F-D (C)	1994	13.985	1.458	No
		1995	14.072	1.851	
		1996	14.081	2.463	
		1997	15.303	1.596	
		1998	22.226	1.684	
		1999	19.362	2.338	
		2000	10.237	2	
		2001	33.691	1.369	
LPS	F-D (R)	1986	1.58	0.108	Yes
		1987	1.55	0.157	
		1988	2.92	0.105	

		1989	2.65	0.056	
		1990	0.82	0.121	
		1991	0.77	0.119	
		1992	1.36	0.133	
		1993	0.24	0.727	
		1994	0.23	0.443	
		1995	0.44	0.61	
		1996	0.25	0.445	
		1997	0.99	0.376	
		1998	0.14	0.753	
		1999	0.28	0.678	
		2000	0.13	1.848	
		2001	1.66	0.42	
Blacktip shark					
PLL	F-D (C)	1992	1.455	0.234	Yes
		1993	1.602	0.129	
		1994	1.220	0.134	
		1995	0.817	0.167	
		1996	0.886	0.171	
		1997	0.735	0.192	
		1998	0.655	0.209	
		1999	0.727	0.211	
		2000	0.588	0.332	
		2001	1.314	0.234	
Early Rec	F-D (R)	1981	1.738	1	No
		1982	0.634	1	
		1983	0.443	1	
		1984	0.618	1	
		1985	0.703	1	
		1986	1.437	1	
		1987	0.952	1	
		1988	0.990	1	
		1989	0.832	1	
		1990	1.159	1	
		1991	1.202	1	
		1992	1.556	1	
		1993	0.735	1	
Late Rec	F-D (R)	1994	1.243	1	No
		1995	0.620	1	
		1996	0.894	1	
		1997	0.734	1	
		1998	1.861	1	
		1999	0.453	1	
		2000	1.195	1	
Shark observer	F-D (C)	1994	3.364	4.454	No
		1995	6.701	2.108	
		1996	4.327	2.542	
		1997	0.975	6.814	
		1998	5.746	3.437	
		1999	6.156	2.672	
		2000	9.758	2.513	
		2001	1.048	3.250	
NMFS LL NE early	F-I	1989	0.06	0.247	No
		1991	0.13	0.161	
NMFS LL NE late	F-I	1996	0.025	4.769	No

		1998	0.135	2.575	
		2001	0.075	2.792	
NMFS LL SE	F-I	1995	0.801	0.371	Yes
		1996	0.760	0.401	
		1997	1.198	0.226	
		1999	0.904	0.236	
		2000	1.337	0.258	
BLL Logs ST	F-D (C)	1996	0.646	0.263	Yes
		1997	0.714	0.224	
		1998	0.848	0.215	
		1999	1.217	0.202	
		2000	1.125	0.224	
		2001	1.415	0.203	
Driftnet observer	F-D (C)	1993	0.866	2.068	Yes
		1994	2.100	0.649	
		1995	1.653	1.781	
		1998	0.106	4.396	
		1999	0.678	0.441	
		2000	0.848	0.392	
		2001	0.749	0.35	
SC LL late	F-I	1995	33.298	0.384	Yes
		1996	15.379	0.437	
		1997	39.835	0.276	
		1998	9.272	0.525	
		1999	9.169	0.652	
		2000	21.832	0.291	
		2001	4.407	1.123	

Age-structured analyses

Sandbar					
Virginia LL (biomass)	F-I	1974	12.586	0.137	No
(all ages)		1975	12.586	0.137	
		1976	12.586	0.137	
		1977	12.586	0.137	
		1978	12.586	0.137	
		1979	12.586	0.137	
		1980	18.742	0.128	
		1981	21.480	0.123	
		1982	6.485	0.176	
		1983	6.485	0.176	
		1984	6.485	0.176	
		1985	6.485	0.176	
		1986	8.120	0.223	
		1987	8.120	0.223	
		1988	8.120	0.223	
		1989	8.120	0.223	
		1990	1.329	0.348	
		1991	1.412	0.354	
		1992	0.548	0.425	
		1993	1.526	0.537	
		1995	2.596	0.229	
		1996	2.668	0.241	
		1997	2.595	0.204	
		1998	3.239	0.200	
		1999	2.438	0.328	

		2000	3.115	0.226	
Virginia LL (ages 0-1)	F-I	1980	2.042	1.000	No
		1981	1.261	1.000	
		1990	0.088	1.000	
		1993	0.179	1.000	
		1995	1.546	1.000	
		1996	1.416	1.000	
		1997	3.633	1.000	
		1998	2.617	1.000	
		1999	0.325	1.000	
		2000	2.599	1.000	
Virginia LL (ages 2-7)	F-I	1980	3.191	1.000	No
		1981	3.537	1.000	
		1990	0.161	1.000	
		1991	0.356	1.000	
		1992	0.065	1.000	
		1995	1.264	1.000	
		1996	1.133	1.000	
		1997	0.741	1.000	
		1998	2.168	1.000	
		1999	2.235	1.000	
		2000	1.813	1.000	
Virginia LL (ages 8-12)	F-I	1980	2.330	1.000	No
		1981	3.679	1.000	
		1990	2.374	1.000	
		1991	0.546	1.000	
		1992	0.241	1.000	
		1995	0.457	1.000	
		1996	0.822	1.000	
		1997	0.451	1.000	
		1998	0.298	1.000	
		1999	0.569	1.000	
		2000	0.233	1.000	
Virginia LL (ages 13-maximum)	F-I	1980	4.431	1.000	No
		1981	3.772	1.000	
		1990	0.826	1.000	
		1991	0.583	1.000	
		1993	0.363	1.000	
		1995	0.173	1.000	
		1996	0.173	1.000	
		1997	0.456	1.000	
		1998	0.144	1.000	
		1999	0.495	1.000	
		2000	0.583	1.000	
PLL (ages 13-maximum)	F-D (C)	1994	0.416	0.302	Yes
		1995	0.923	0.108	
		1996	1.126	0.110	
		1997	0.906	0.119	
		1998	0.961	0.129	
		1999	1.048	0.128	
		2000	1.486	0.164	
		2001	1.134	0.183	
Early Rec (ages 2-7)	F-D (R)	1981	1.024	1.000	No
		1982	1.213	1.000	
		1983	3.967	1.000	
		1984	1.244	1.000	

		1985	0.847	1.000	
		1986	1.574	1.000	
		1987	0.678	1.000	
		1988	0.544	1.000	
		1989	0.217	1.000	
		1990	0.517	1.000	
		1991	0.372	1.000	
		1992	0.431	1.000	
		1993	0.373	1.000	
Late Rec	F-D (R)	1994	0.559	1.000	No
(ages 2-7)		1995	0.745	1.000	
		1996	1.017	1.000	
		1997	1.295	1.000	
		1998	1.578	1.000	
		1999	1.178	1.000	
		2000	0.628	1.000	
Shark observer	F-D (C)	1994	13.985	1.458	No
(all ages)		1995	14.072	1.851	
		1996	14.081	2.463	
		1997	15.303	1.596	
		1998	22.226	1.684	
		1999	19.362	2.338	
		2000	10.237	2.000	
		2001	33.691	1.369	
NMFS LL NE early	F-I	1989	2.514	0.395	No
(all ages)		1991	0.982	0.458	
NMFS LL NE late	F-I	1996	0.399	2.952	No
(all ages)		1998	2.395	2.418	
		2001	1.240	2.739	
NMFS LL SE	F-I	1995	1.971	0.952	Yes
(all ages)		1996	0.299	5.691	
		1997	0.939	1.354	
		1999	0.668	2.747	
		2000	1.123	1.165	
SC LL early	F-I	1983	4.730	1.000	No
(ages 1-12)		1994	0.410	1.000	
SC LL recent	F-I	1995	14.522	1.049	Yes
(ages 1-12)		1996	30.581	0.446	
		1997	20.399	0.576	
		1998	23.811	0.377	
		1999	80.817	0.207	
		2000	21.131	0.396	
		2001	30.830	0.344	
BLL Logs ST	F-D (C)	1996	0.664	0.195	Yes
(all ages)		1997	0.955	0.154	
		1998	0.881	0.148	
		1999	1.233	0.138	
		2000	1.152	0.154	
		2001	1.114	0.148	
LPS	F-D (R)	1986	1.580	0.108	Yes
(all ages)		1987	1.550	0.157	
		1988	2.920	0.105	
		1989	2.650	0.056	
		1990	0.820	0.121	
		1991	0.770	0.119	
		1992	1.360	0.133	

		1993	0.240	0.727	
		1994	0.230	0.443	
		1995	0.440	0.610	
		1996	0.250	0.445	
		1997	0.990	0.376	
		1998	0.140	0.753	
		1999	0.280	0.678	
		2000	0.130	1.848	
		2001	1.660	0.420	
Blacktip					
PLL	F-D (C)	1992	1.455	0.234	Yes
(ages 6-maximum)		1993	1.602	0.129	
		1994	1.220	0.134	
		1995	0.817	0.167	
		1996	0.886	0.171	
		1997	0.735	0.192	
		1998	0.655	0.209	
		1999	0.727	0.211	
		2000	0.588	0.332	
		2001	1.314	0.234	
Early Rec	F-D (R)	1981	1.738	1.000	No
(ages 0-3)		1982	0.634	1.000	
		1983	0.443	1.000	
		1984	0.618	1.000	
		1985	0.703	1.000	
		1986	1.437	1.000	
		1987	0.952	1.000	
		1988	0.990	1.000	
		1989	0.832	1.000	
		1990	1.159	1.000	
		1991	1.202	1.000	
		1992	1.556	1.000	
		1993	0.735	1.000	
Late Rec	F-D (R)	1994	1.243	1.000	No
(ages 0-3)		1995	0.620	1.000	
		1996	0.894	1.000	
		1997	0.734	1.000	
		1998	1.861	1.000	
		1999	0.453	1.000	
		2000	1.195	1.000	
Shark observer	F-D (C)	1994	3.364	4.454	No
(all ages)		1995	6.701	2.108	
		1996	4.327	2.542	
		1997	0.975	6.814	
		1998	5.746	3.437	
		1999	6.156	2.672	
		2000	9.758	2.513	
		2001	1.048	3.250	
NMFS LL NE early	F-I	1989	0.060	0.2474	No
(all ages)		1991	0.130	0.161	
NMFS LL NE late	F-I	1996	0.025	4.769	No
(all ages)		1998	0.135	2.575	
		2001	0.075	2.792	
NMFS LL SE	F-I	1995	0.801	0.371	Yes
(all ages)		1996	0.760	0.401	

		1997	1.198	0.226	
		1999	0.904	0.236	
		2000	1.337	0.258	
BLL Logs ST (all ages)	F-D (C)	1996	0.646	0.263	Yes
		1997	0.714	0.224	
		1998	0.848	0.215	
		1999	1.217	0.202	
		2000	1.125	0.224	
		2001	1.415	0.203	
Driftnet observer (all ages)	F-D (C)	1993	0.866	2.068	Yes
		1994	2.100	0.649	
		1995	1.653	1.781	
		1998	0.106	4.396	
		1999	0.678	0.441	
		2000	0.848	0.392	
		2001	0.749	0.350	
SC LL recent (ages 0-5)	F-I	1995	33.298	0.384	Yes
		1996	15.379	0.437	
		1997	39.835	0.276	
		1998	9.272	0.525	
		1999	9.169	0.652	
		2000	21.832	0.291	
		2001	4.407	1.123	
PC LL (ages 0-5)	F-I	1993	1.928	0.427	Yes
		1994	0.324	0.428	
		1995	0.746	0.438	
		1996	0.910	0.329	
		1997	1.550	0.270	
		1998	1.170	0.450	
		1999	0.787	0.373	
		2000	0.586	0.429	
PC gillnet (ages 1-5)	F-I	1996	0.795	0.292	Yes
		1997	1.511	0.268	
		1998	1.191	0.343	
		1999	1.150	0.412	
		2000	0.404	0.760	
		2001	0.948	0.430	
PC gillnet (age 0)	F-I	1996	0.083	3.189	Yes
		1997	0.522	0.679	
		1998	0.462	0.841	
		1999	1.919	0.426	
		2000	0.705	0.873	
		2001	2.309	0.364	
Mote gillnet (age 0)	F-I	1995	0.010	0.544	No
		1996	0.046	0.943	
		1997	0.005	1.422	
		1999	0.006	0.942	
		2000	0.006	0.883	
		2001	0.010	0.739	