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Assessment of Large Coastal, Blacktip, and Sandbar Sharks using Surplus Production Methods

E. Cortés[1] and E.A. Babcock[2]

[1] NOAA Fisheries Service
NMFS SEFSC
Panama City Laboratory
3500 Delwood Beach Drive,
Panama City, FL 32408, USA

[2] Pew Institute for Ocean Science
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149, USA

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Summary

We used two complementary surplus production models (BSP and WinBUGS) to assess the status of three Large Coastal Shark (LCS) groupings, two stocks of blacktip shark, and a single stock of sandbar shark identified as baseline scenarios in the LCS Data Workshop report. Both methodologies use Bayesian inference to estimate stock status, and the BSP further performs Bayesian decision analysis to examine the sustainability of various levels of future catch. Extensive sensitivity analyses were performed with the BSP model to assess the effect of different assumptions on CPUE indices and weighting methods, catches, intrinsic rates of increase, initial depletion, and importance function on results. Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Using the inverse variance method to weight the CPUE data

changed the predictions on stock status for the LCS grouping, which would then be overfished, with overfishing occurring. The sandbar shark stock was estimated to be significantly depleted (64-71% depletion from virgin level). The Gulf of Mexico blacktip shark stock was healthy (depletion of only 8-23% of virgin level), whereas results for the Atlantic blacktip shark stock from the BSP and WinBUGS models conflicted. The BSP model predicted a considerable level of depletion for this stock regardless of the CPUE weighting method used. In contrast, the assessment of a single blacktip shark stock (GOM+ATL) resulted in very consistent results, with all models predicting a healthy status (depletions of only 10-16% of virgin level). Using the higher values of r from the 2002 SEW or accounting for some depletion from virgin levels in the first year of the model did not affect conclusions. Several assumptions on catches (notably changing the high value of recreational catch in 1983) also had no effect on conclusions. Removing the VIMS CPUE series from the LCS scenario reversed the conclusions on stock status when using inverse variance weighting, highlighting the influence of this series on results; removing the PLL CPUE series from the ATL blacktip shark analysis also drastically reversed the conclusions on stock status. Adding one CPUE series at a time had a larger effect on results: the PLL series greatly influenced conclusions for the three LCS groupings and GOM and ATL blacktip shark, whereas the VIMS series affected conclusions on the two groups for which it is available, LCS and sandbar shark.

1. Introduction/Background

The Large Coastal Shark (LCS) complex has traditionally been assessed using surplus production methods because it consists of a variety of species with widely varying life histories and for some of which both biological and fishery data are very limited, preventing the use of single-species, age-structured models in many cases. The Data Workshop (DW) report of the LCS complex, blacktip, and sandbar sharks identifies three separate groupings of LCS: 1) LCS as originally defined (consisting of 22 species), 2) LCS without species presently classified by NMFS as prohibited (11 species), and 3) LCS without prohibited, sandbar, or blacktip sharks (9 species). These three groupings respond to an effort on the part of the DW participants to attempt to examine the effect of prohibited species and the two most important species in the fishery—blacktip and sandbar sharks—on stock assessment results. Additionally, the DW report identified two separate stocks of blacktip shark (Gulf of Mexico and Atlantic) and one single stock of sandbar shark as baseline scenarios for assessment. The present document thus examines six baseline scenarios (three for LCS, two for blacktip, and one for sandbar) and additional sensitivity analyses are explored.

The last stock assessment of LCS, blacktip and sandbar sharks conducted (Cortés et al. 2002) made use of the same two surplus production methodologies used in the present document: the BSP and WinBUGS. As has been reported before, use of these two methods in tandem allows us to examine the effect of different model structural assumptions (e.g., consideration of observation error alone vs. observation and process error) and methods for numerical integration (SIR vs. MCMC). The BSP also provides a flexible framework for examining the effects of the importance function used for Bayesian estimation (priors vs. multivariate) and numerous other technical issues, in addition to conducting Bayesian decision analysis to project into the future population status and estimate performance indicators under various levels of catch or fishing mortality.

2. Materials and Methods

2. 1. Model description

Bayesian Surplus Production (BSP) model

The Bayesian Surplus Production (BSP) model program fits a Schaefer model to CPUE and catch data using the SIR algorithm. The BSP software is available, for example, in the ICCAT catalog of methods (McAllister and Babcock 2004) and has been used as the base model in previous assessments of large coastal sharks. Herein we used the discrete-time version of the model (although the continuous form is also implemented by the software), so that:

$$B_{t+1} = B_t + rB_t - \frac{r}{K} B_t^2 - C_t$$

where B_t= biomass at the beginning of year t, r is the intrinsic rate of increase, K is carrying capacity and C_t is the catch in year t.

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

$$\hat{I}_{j,t} = q_j B_t e^{\varepsilon_t}$$

where q_j is the catchability coefficient for CPUE series j, and ε_t is the residual error, which is assumed to be lognormally distributed. The program allows for a variety of methods to weight CPUE data points. As recommended in the DW report, we used equal weighting (or no weighting; method 1) in all baseline scenarios. The model log-likehood is given by:

$$\ln L = -\sum_j \sum_y \frac{\left[\ln(I_{j,y}) - \ln(\hat{q}_j \hat{B}_y)\right]^2}{2\sigma_{j,y}{}^2}$$

were $I_{j,y}$ is the CPUE in year y for series j, $\hat{q}_j$ is the constant of proportionality for series j, $\hat{B}_y$ is the estimated biomass in year y, and $\sigma_{j,y}{}^2$ is the variance (=1/weight; in this case weight=1) applied to series j in year y.

In the inverse variance method (method 3), the annual observations are proportional to the annual CV^2 (if available) and the average variance for each series is equal to the MLE estimate. The log likelihood function is expressed as:

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

where s is the number of CPUE series, y is the number of years in each CPUE series, $CV_{j,t}{}^2$ is the coefficient of variation for series j in year t, c_j is a constant of proportionality for each series j chosen such that the average variance for each series equals its estimated average variance, σ_j^2 (the MLE estimate). The catchability coefficient for each time series (q_j) is also estimated as the MLE such that:

$$\hat{q}_j = e^{\left(\frac{\sum_{t=1}^{t=y} \left(\ln(I_{j,t}) - \ln(\widehat{B}_t) \right) / c_j CV_{j,t}{}^2 \widehat{\sigma_j{}^2}}{\sum_{t=1}^{t=y} 1/(c_j CV_{j,t}{}^2 \widehat{\sigma_j{}^2})} \right)}$$

WinBUGS Bayesian Surplus Production Model

This implementation of the Schaefer surplus production model uses Gibbs sampling, an MCMC method of numerical integration, to sample from the posterior distribution using WinBUGS (Spiegelhalter et al. 2000). The model was originally developed by Meyer and Millar (1999a) and modified by Cortés (2002) and Cortés et al. (2002) to apply it to small and large coastal sharks, respectively. To minimize correlations between model parameters and speed mixing of the Gibbs sampler, the surplus production model is reparameterized by expressing the annual biomass as a proportion of carrying capacity:

$$P_t = P_{t-1} + rP_{t-1}(1 - P_{t-1}) - \frac{C_{t-1}}{K} e^{P_t}$$

where $P_t = B_t/K$. The model is a state-space model, which relates the observed catch rates (I_t) to unobserved states (B_t) through a stochastic observation model for I_t given Bt (Millar and Meyer 1999, Meyer and Millar 1999b):

$$I_t = qKP_t e^{O_t}$$

The model thus assumes lognormal error structures for both process and observation errors (e^P and e^O), with $P_t \sim N(0,\sigma^2)$ and $O_t \sim N(0,\tau^2)$. In the present implementation, the catchability coefficient for each CPUE series is taken as the MLE.

The crucial equation for Bayesian inference is the joint posterior distribution of the unobservable states given the data, which is equal to the product of the joint prior distribution and the sampling distribution (likelihood):

$$\begin{aligned} & p(K, r, q, C_0, B_{74}/K, \sigma^2, \tau^2, P_1, ..., P_n, I_1, ..., I_n) = \\ & p(K)\, p(r)\, p(q)\, p(C_0)\, p(B_{74}/K)\, p(\sigma^2)\, p(\tau^2)\, p(P_1 \mid \sigma^2) \\ & \times \prod_{i=2}^{i=m+1} p(P_t \mid P_{t-1}, K, r, C_0, \sigma^2) \prod_{i=m+2}^{i=n} p(P_t \mid P_{t-1}, K, r, \sigma^2) \prod_{t=1}^{t=n} p(I_t \mid P_t, q, \tau^2) \end{aligned}$$

where, in this case, m is the number of years of unobserved catches (C_0).

2. 2. Data inputs, prior probability distributions, and performance indicators

LCS—Catch data were available from 1981 to 2004 (Table 2.2 of the DW) and CPUE data, from 1972 to 2004 (Table 3.2 of the DW). Eleven CPUE series identified as "base" in the DW report were used in the baseline scenario. The fishery was assumed to begin in 1972, the first year for which CPUE data were available. The catches in the years 1972-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (534.9 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. Other estimated parameters were r, K, and the abundance (in numbers) in 1972 relative to K (N_{72}/K). The constant of proportionality between each abundance index and the biomass trend was calculated using the numerical shortcut of Walters and Ludwig (1994). The prior for K was uniform on log (K), weakly favoring smaller values, and was allowed to vary between 10^5 and 10^9 individuals. Informative, lognormally distributed priors were used for N_{72}/K and r. For N_{72}/K, the mean was set equal to 1, and the log-SD was 0.2. For r, the mean value was taken as recommended in the DW report when considering density dependence (0.045 yr^{-1}). Since no SD was provided in the report, we used a value that would correspond to the same proportion of the mean as used in the 2002 SEW (i.e., the mean r in the 2002 SEW was 0.113, with a log-variance of 0.49 [the BSP uses variance as an input], so the value of log-variance corresponding to a mean of 0.045 is 0.195).

LCS without prohibited species—Catch data were available from 1981 to 2004 (Table 2.3 of the DW) and CPUE data, only from 1992 to 2004 (Table 3.2 of the DW). Seven CPUE series identified as "base" in the DW report were used in the baseline scenario. The fishery was assumed to begin in 1972 (for comparison with the LCS scenario). The catches in the years 1972-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (494.6 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{72}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.046 yr^{-1} and the resulting log-variance was 0.199.

LCS without prohibited species, blacktip or sandbar—Catch data were available from 1981 to 2004 (Table 2.4 of the DW) and CPUE data, only from 1992 to 2004 (Table 3.2 of the DW). Seven CPUE series identified as "base" in the DW report were used in the baseline scenario. The fishery was assumed to begin in 1972 (for comparison with the LCS scenario). The catches in the years 1972-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (136.1 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{72}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.043 yr^{-1} and the resulting log-variance was 0.186.

Sandbar shark—Catch data were available from 1981 to 2004 (Table 2.8 of the DW) and CPUE data, from 1975 to 2004 (Table 3.2 of the DW). Eight CPUE series identified as "base" in the DW report were used in the baseline scenario. The fishery was assumed to begin in 1975, the first year for which CPUE data were available. The catches in the years 1975-1980 were assumed to be constant and equal to the model-estimated parameter C_0. The prior for C_0 was lognormal, with a mean equal to the average catch during 1981-2004 (128.1 thousand individuals) and a log-standard deviation (SD) of 1, implying a wide distribution. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{75}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.039 yr^{-1} and the resulting log-variance was 0.164.

Blacktip shark (Gulf of Mexico)—Catch data were available from 1981 to 2004 (Table 2.6 of the DW) and CPUE data, only from 1992 to 2004 (Table 3.2 of the DW). Five CPUE series identified as "base" in the DW report were used in the baseline scenario. The fishery was assumed to begin in 1981, the first year for which catch data were available, and thus C_0 was not required. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{81}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.078 yr^{-1} and the resulting log-variance was 0.28.

Blacktip shark (Atlantic)—Catch data were also available from 1981 to 2004 (Table 2.7 of the DW) and CPUE data, only from 1992 to 2004 (Table 3.2 of the DW). Four CPUE series identified as "base" in the DW report were used in the baseline scenario. The fishery was assumed to begin in 1981, the first year for which catch data were available, and thus C_0 was not required. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{81}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.078 yr^{-1} and the resulting log-variance was 0.28.

The input parameters and priors described above are those used in the BSP model. Model inputs and priors used with WinBUGS were almost exactly the same. Additionally, priors for the observation error variance (τ^2) and process error variance (σ^2) in the WinBUGS model were inverse gamma distributions as used in previous stock assessments (Millar and Meyer 1999, Cortés et al. 2002), i.e., the 10% and 90% quantiles were set at approximately 0.05 and 0.15, and 0.04 and 0.08, respectively.

Performance indicators for the BSP model included the maximum sustainable yield (MSY=rK/4), the stock abundance in the last year of data (N_{2004}), the ratio of stock abundance in the last year of data to carrying capacity and MSY (N_{2004}/K and N_{2004}/MSY), the fishing mortality rate in the last year of data as a proportion of the fishing mortality rate at MSY (F_{2004}/F_{MSY}), the catch in the last year of data as a proportion of the replacement yield (C_{2004}/Ry) and MSY (C_{2004}/MSY), the stock abundance in the first year of the model (B_{init}), and the ratio of stock abundance in the last and first years of the model (B_{2004}/B_{init}). The same metrics, except for those containing replacement yield, were calculated for the WinBUGS model. Additionally, the relative abundance (B_i/B_{MSY}) and fishing mortality (Fi/F_{MSY}) trajectories, as well as the predicted biomass trend, were obtained and plotted for the time period considered in each scenario.

2. 3. Methods of numerical integration, convergence diagnostics, and decision analysis

For the BSP model, numerical integration was carried out using the 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 (depending on which function produced better convergence diagnostics): 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, B_{init}/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 full details). A variance expansion factor of at least 2 was generally used to make the importance function more diffuse (wider) and ensure that the variance of the parameters was not underestimated when using the multivariate Student t distribution.

WinBUGS uses an MCMC method called Gibbs sampling (Gilks et al. 1996) to sample from the joint posterior distribution. 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 100,000 iteration phase.

Convergence diagnostics for the BSP model included the ratio of the CV of the weights to the CV of the product of the likelihood function and the priors, with values <1 indicating convergence and values >10 indicating likely convergence failure, and the maximum weight of any draw as a fraction of the total importance weight, which should be less than 0.5% (SB-02-25; McAllister and Babcock 2004).

In the WinBUGS analyses, convergence of the MCMC algorithm for the two chains was tested by examining the time series history of the two MCMC chains to determine whether mixing was good, parameter autocorrelations, and the convergence diagnostic of Gelman and Rubin (Gelman and Rubin 1992).

For the BSP model, 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 the initial year of the model to 2004, and then forward in time up to 30 years to evaluate the potential consequences of future management actions. The policies considered included setting the total allowable catch (TAC) equal to 0, to the catch in 2003 (2004 was not used because the value is considered preliminary), to 50% of the catch in 2003, and additionally using a constant value of F_{MSY} from 2005 on. The projections included calculating the following reference points, among others: expected value of N_{fin}/K (with fin=2014, 2024, and 2034) and the probabilities that N_{fin} were $< 0.2K$ and $N_{fin} > N_{msy}$.

2. 4. Sensitivity analyses

To examine the impact of the priors and other inputs on the results, sensitivity analyses were performed by changing the following items with respect to those in the baseline scenario one at a time and were implemented with the BSP model. These sensitivity analyses include those identified in the DW report and additional ones.

- Changing the method for weighting the CPUE series: method 3 was used to compare with method 1 in the baseline scenario

- Changing the importance function from the priors to a multivariate t distribution

- Considering a combined (Gulf + Atlantic) blacktip shark scenario
- Using the values of intrinsic rate of increase from the 2002 SEW
- Decreasing the value for the prior of N_{init}/K to a mean=0.85. This prior reduces the probability that N_{init}/K will be much higher than K (18% of the pdf is >1 with this prior vs. 45% if the mean=1)
- Considering an alternative catch series for LCS (Table 2.5 of the DW) to compensate for under-reporting of landings during the earliest years of the time series (1981-1994)
- Changing the value of recreational catch for 1983 to the geometric mean value of the 1982 and 1984 estimates in the three LCS and sandbar shark scenarios
- Removing one CPUE series at a time from the full model (with all CPUE series considered in the baseline scenario) and using inverse variance weighting (method 3)
- Including only one CPUE series (of those considered in the baseline scenario) at a time and using inverse variance weighting (method 3)

3. Results

3.1. Baseline scenarios

LCS—Although the two longest series (ENP and VIMS) showed a declining trend in the early years (1970s and 1980s), all series were rather flat or showed a slightly increasing tendency in the early 2000s (Fig. 1). The abundance trajectory at the mode of the posterior distribution showed a similar trend, decreasing from the early 1970s to the mid-1990s, and slightly increasing thereafter. The median relative biomass trajectory indicated that the stock did not reach an overfished status in any year (Fig. 2A), whereas the median relative fishing mortality trajectory indicated that overfishing had occurred from the early 1980's to the late 1990's, but was no longer occurring from 1999 on (Fig. 2B). The model did not fit the early years of the VIMS and PLL CPUE series well (Fig. 2C).

Current status of the population was above B_{MSY} and no overfishing was occurring (Table 1). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distributions of K and r showed that the data supported relatively high values of these two parameters, whereas the posterior for C_0 was very similar to the prior distribution (Fig. 3). Population projections showed that the population would be expected to remain above B_{MSY} for at least 30 years even under the current (for 2003) level of total catch (Table 2).

The predicted median abundance trajectory for the WinBUGS model showed a very similar trend to that of the mode from the BSP model, decreasing from the early 1970s to the mid-1990s, and slightly increasing thereafter (Fig. 4A). The median relative biomass trajectory also indicated that the stock did not reach an overfished status in any year (Fig. 4B), whereas the median relative fishing mortality trajectory indicated that overfishing had occurred from the late 1980's to the mid 1990's, but was no longer occurring from 1997 on (Fig. 4C). Current status of the population was thus above B_{MSY} and no overfishing was occurring (Table 3). WinBUGS model fits to the CPUE series were similar to those obtained with the BSP model, with the majority showing flat or slightly increasing tendencies, and poor fit to the early years of the VIMS and PLL CPUE series (Fig. 5). Convergence diagnostics for the WinBUGS model showed that there was good mixing of the two chains for all parameters. Autocorrelations for all parameters also decreased after an initial lag, but remained high for some parameters. The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest (the ratio of the width of the central 80% interval of the pooled runs and the average width of the 80% intervals within the individual runs converged to 1 and both the pooled and within interval widths stabilized).

LCS without prohibited species—The earliest CPUE data point went back to 1992 only, and with the exception of the PLL series, all remaining series showed increasing tendencies (Fig. 6). The abundance trajectory at the mode of the posterior distribution predicted a slow decrease starting in the early 1980s that progressively decelerated towards the end of the time series. Accordingly, the median relative biomass and fishing mortality trajectories indicated that the stock did not reach an overfished status and that overfishing did not occur for the duration of the time series (Fig. 7A and B). Model fits to the CPUE series were all rather flat, probably as a result of the model trying to compensate between the decreasing trend from the PLL series and the generally increasing tendencies of all remaining CPUE series (Fig. 7C).

Current status of the population was above B_{MSY} and no overfishing was occurring (Table 1). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distribution of K showed that the data supported relatively high values of this parameter (more so than in the LCS scenario), whereas the posteriors of r and C_0 were almost identical to those in the LCS scenario (Fig. 8). Population projections showed that the population would be expected to remain above B_{MSY} for at least 30 years even under the current (for 2003) level of total catch and were a little more optimistic than for the LCS scenario (Table 2).

The predicted median abundance trajectory for the WinBUGS model showed a similar trend to that of the mode from the BSP model, but it actually increased from 1996 on (Fig. 9A). The median relative biomass trajectory mirrored that trend, indicating that the stock did not reach an overfished status in any year (Fig. 9B), whereas the median relative fishing mortality trajectory indicated that overfishing had occurred in the early part of the time series, but was no longer occurring (Fig. 9C). Current status of the population was thus above B_{MSY} and no overfishing was occurring (Table 3). WinBUGS model fits to the CPUE series all showed a flat or slightly increasing tendency and as with the BSP some of the fits were relatively poor (Fig. 10). Convergence diagnostics for the WinBUGS model showed that there was good mixing of the two chains for all parameters. Autocorrelations for all parameters also decreased after an initial lag, but remained high for some parameters as in the LCS scenario. The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest.

LCS without prohibited species, blacktip or sandbar—The earliest CPUE data point also went back to 1992 only, and with the exception of the PLL series, all remaining series also showed increasing tendencies (Fig. 11). The abundance trajectory at the mode of the posterior distribution predicted a slow decrease starting in the early 1980s that progressively decelerated and became flat towards the end of the time series. Accordingly, the median relative biomass and fishing mortality trajectories indicated that the stock did not reach an overfished status and that overfishing did not occur for the duration of the time series (Fig. 12A and B). Model fits to the CPUE series were all flat, as in the case above probably as a result of the model trying to compensate between the decreasing trend from the PLL series and the increasing tendencies of all remaining CPUE series (Fig. 12C).

Current status of the population was the most optimistic from the three LCS scenarios, being above B_{MSY} and with no overfishing occurring (Table 1). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distribution of K showed that the data supported relatively high values of this parameter (to a degree intermediate between the two scenarios considered above), the posterior of r was almost identical to that in the LCS scenario, and the posterior of C_0 favored smaller values than predicted in the two previous scenarios (Fig. 13). Population projections showed that the population would be expected to remain above B_{MSY} for at least 30 years even under the current (for 2003) level of total catch and were the most optimistic of the three LCS scenarios (Table 2).

The predicted median abundance trajectory for the WinBUGS model showed a similar trend to that of the mode from the BSP model, but it also actually increased from 1996 on (Fig. 14A). The median relative biomass trajectory mirrored that trend, indicating that the stock did not reach an overfished status in any year (Fig. 14B), whereas the median relative fishing mortality trajectory indicated that overfishing had occurred in the early part of the time series, but was no longer occurring (Fig. 14C). Current status of the population was thus above B_{MSY} and no overfishing was occurring (Table 3). WinBUGS model fits to the CPUE series all showed slightly increasing tendencies and as with the BSP some of the fits were relatively poor (Fig. 15). Convergence diagnostics for the WinBUGS model showed that there was good mixing of the two chains for all parameters. Autocorrelations for all parameters also decreased after an initial lag, but remained high for some parameters as in the other two LCS scenarios. The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest.

Sandbar shark—The two longest series (VIMS and LPS) showed oscillations, but presented a markedly declining trend from beginning to end. All the other series, which covered the 1990s and 2000s, showed no clear trend (Fig. 16). The abundance trajectory at the mode of the posterior distribution predicted a marked decrease from beginning to end of the time series. Accordingly, the median relative biomass and fishing mortality trajectories indicated that the stock reached an overfished status after 1991 and that overfishing occurred essentially during the whole time series (Fig. 17A and B). Model fits to the CPUE series were all declining, and while the fit was satisfactory for the VIMS series (the model attempted to track the early values in that series), it was poor for the early years of the LPS series, the other markedly declining, long-duration series (Fig. 17C).

Current status of the population was well below B_{MSY} and high overfishing was occurring (Table 1). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distribution of K showed that the data supported much lower values of this parameter than those for the three LCS scenarios, the data also supported higher values of r than inputted in the prior, and the posterior of C_0 favored values very similar to those predicted in the previous scenario (Fig. 18). Population projections indicated that the population would not reach B_{MSY} until at least 30 years with a no-catch policy (Table 2).

The predicted median abundance trajectory for the WinBUGS model showed a similar trend to that of the mode from the BSP model (Fig. 19A). The median relative biomass trajectory mirrored that trend, indicating that the stock had reached an overfished status after 1986 and that overfishing occurred essentially during the whole time series, except for a few isolated years, including 2004 (median value of F/F_{MSY}=0.91; Fig. 19B and Table 3). WinBUGS model fits to the CPUE series were slightly declining, except for the fit to the VIMS series, which was more markedly negative. As with the BSP model, WinBUGS attempted to track the early values in the VIMS series, providing a good fit, but also fit poorly the early years of the LPS series (Fig. 20). Convergence diagnostics for the WinBUGS model showed that there was good mixing of the two chains for all parameters. Autocorrelations for all parameters also decreased after an initial lag, but remained high for some parameters as in the previous scenarios. The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest.

Blacktip shark (Gulf of Mexico)—The earliest CPUE data point also went back to 1992 only, and with the exception of the PLL series, all remaining series showed increasing tendencies (Fig. 21). The abundance trajectory at the mode of the posterior distribution showed a rather pronounced decrease, but the median biomass trajectory (not depicted in Fig. 21) did not. The median relative biomass and fishing mortality trajectories indicated that the stock did not reach an overfished status and that overfishing did not occur for the duration of the time series (Fig. 22A and B). Interestingly, model fits to the CPUE series were all decreasing (Fig. 22C).

Current status of the population was above B_{MSY} and no overfishing was occurring (Table 1). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distribution of K showed that the data supported relatively high values of this parameter and was very similar to that in the LCS without prohibited species, sandbar or blacktip scenario. The posterior of r also supported higher values for this parameter, but less so than in the other scenarios, and this scenario was the only one in which the posterior of C_0 favored somewhat smaller values than the prior (Fig. 23). Population projections showed that the population would be expected to remain above B_{MSY} even under the current (for 2003) level of total catch (Table 2).

The predicted median abundance trajectory for the WinBUGS model showed a slightly increasing trend that leveled off from the early 1990s on (Fig. 24A). The median relative biomass trajectory mirrored that trend, indicating that the stock did not reach an overfished status in any year (Fig. 24B) and the median relative fishing mortality trajectory indicated that overfishing did not occur in any year (Fig. 24C). Current status of the population was thus above B_{MSY} and no overfishing was occurring (Table 3). Unlike the BSP model, WinBUGS model fits to the CPUE series all showed slightly increasing tendencies, but the fits were of similar quality to those obtained with the BSP model (Fig. 25). Convergence diagnostics for the WinBUGS model showed that there was good mixing of the two chains for all parameters. Autocorrelations for all parameters also decreased after an initial lag, but remained high for some parameters as in all other scenarios. The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest.

Blacktip shark (Atlantic)— The earliest CPUE data point also went back to 1992 only, and with the exception of the PLL series, all three remaining series showed no clear or slightly increasing trends (Fig. 26). The abundance trajectory at the mode of the posterior distribution showed a steep decrease. The median relative biomass and fishing mortality trajectories indicated that the stock became overfished in 1994 and that overfishing started to occur in 1991 (Fig. 27A and B, respectively). All model fits to the CPUE series were decreasing (Fig. 27C).

Current status of the population was below B_{MSY} and overfishing was occurring (Table 1). The priors were used as an importance function for importance sampling. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV(weights) / CV(likelihood * priors) <1). The posterior distributions of K and r showed that the data supported only slightly higher values of these two parameters. The posterior of C_0 was almost identical to the prior (Fig. 28). Projections indicated that the population would reach B_{MSY} only under a no-catch policy and in 20 years (Table 2).

Results with the WinBUGS model were very different. The predicted median abundance trajectory showed a flat trend (Fig. 29A), mirrored by the median relative biomass trajectory, indicating that the stock did not reach an overfished status in any year (Fig. 29B). The median relative fishing mortality trajectory indicated that overfishing did not occur in any year (Fig. 29C). Current status of the population was well above B_{MSY} and no overfishing was occurring (Table 3). WinBUGS model fits to the CPUE series all showed very little trend, and this model did not attempt to track the early decrease in the PLL series as did the BSP model (Fig. 30). As with all other baseline scenarios, convergence diagnostics for the WinBUGS model showed that there was good mixing of the two chains for all parameters. Autocorrelations for all parameters also decreased after an initial lag, but remained high for some parameters as in all other scenarios. The Gelman-Rubin diagnostic indicated good convergence for the main parameters of interest.

3.2. Sensitivity analyses

Changing the CPUE weighting method—We focused on changing the CPUE weighting method from equal weighting (method 1; baseline) to inverse variance weighting (method 3). We report only those results obtained with the importance function (prior vs. multivariate t) that produced the best convergence diagnostics.

LCS—Current status of the population worsened considerably, dipping below B_{MSY} and overfishing occurred when considering this change (Table 4). The multivariate t distribution as an importance function yielded better convergence diagnostics than the priors for the SIR algorithm (maximum weight of any draw <0.5%, but CV (weights) / CV (likelihood * priors) was 1.22). Population projections estimated only a 33% probability of the population reaching B_{MSY} even after 30 years under the current level of total catch, whereas a 50% reduction in total catch would result in a 65% probability of the population reaching B_{MSY} in only 10 years (Table 5).

LCS without prohibited species—This change had little impact on results, with current status of the population improving with respect to the baseline scenario (Table 4). The priors as an importance function yielded better convergence diagnostics than the multivariate t distribution for the SIR algorithm (maximum weight of any draw <0.5%, but CV (weights) / CV (likelihood * priors) was 1.21). As in the baseline scenario, population projections were very optimistic, with no risk of the population going below B_{MSY} under any of the policies or time horizons considered (Table 5).

LCS without prohibited species, blacktip or sandbar—This change had even less impact on results than the previous one, with F_{2004}/F_{MSY} decreasing from 0.30 (baseline scenario) to 0.23 scenario (Table 4). The priors as an importance function yielded better convergence diagnostics than the multivariate t distribution for the SIR algorithm (maximum weight of any draw <0.5%, but CV (weights) / CV (likelihood * priors) was 1.11). As in the previous case, population projections were very optimistic, with no risk of the population going below B_{MSY} under any of the policies or time horizons considered (Table 5).

Sandbar shark—Importance sampling did not converge for sandbar shark when using the inverse variance weighting method.

Blacktip shark (Gulf of Mexico)— Current status of the population improved (Table 4). The multivariate t distribution as an importance function yielded better convergence diagnostics than the priors for the SIR algorithm (but maximum weight of any draw =0.65%, CV (weights) / CV (likelihood * priors) < 1). The expected value of r was unrealistically high (1.04) and that of K, unrealistically low (about 1 million animals). Again, population projections were very optimistic, with no risk of the population going below B_{MSY} under any of the policies or time horizons considered (Table 5).

Blacktip shark (Atlantic)— This scenario only converged when all CVs in the BLLOP CPUE series were set equal to 1. Current status of the population was severely depleted and high overfishing was occurring (Table 4). The priors as an importance function yielded better convergence diagnostics than the multivariate t distribution for the SIR algorithm (but maximum weight of any draw =0.73%, CV (weights) / CV (likelihood * priors) < 1). Population projections were very pessimistic, with only a 46% probability of the population reaching B_{MSY} after 30 years even under a no-catch policy (Table 5).

Considering a combined (Gulf + Atlantic) blacktip shark scenario—The catch series developed for this sensitivity analysis is detailed in document SEDAR11-AW-0x. The five CPUE series used (DGNOP, PCGN, BLLOP, NMFSLLSE, and CFL) were developed before and after the DW and are summarized in the various documents presented to the DW. As with the scenarios for blacktip GOM and blacktip ATL, catch data were available from 1981 to 2004 and CPUE data, only from 1993 to 2004. The fishery was assumed to begin in 1981, the first year for which catch data were available, and thus C_0 was not required. The prior for K was uniform on log (K), and ranged between 10^5 and 10^9 individuals. The mean of N_{81}/K was set to 1 and the log-SD to 0.2. The mean value of r as recommended in the DW report when considering density dependence was 0.078 yr^{-1} and the resulting log-variance was 0.28. We used the BSP model with both equal and inverse variance weighting as well WinBUGS to explore this scenario.

Current status of the population was well above B_{MSY} and no overfishing was occurring under the BSP with equal or inverse variance weighting (Table 6). The priors were used as an importance function for importance sampling in both cases. The SIR algorithm converged with good diagnostics of convergence (maximum weight of any draw <<0.5%, CV (weights) / CV (likelihood * priors) <1). Results obtained with WinBUGS were very similar (Table 6).

Using the values of intrinsic rate of increase from the 2002 SEW—This change was explored using the equal weighting method and had little impact on results. Thus, none of the conclusions obtained in the baseline scenarios changed (compare Tables 1 and 7).

Decreasing the value for the prior of N_{init}/K—Reducing the mean value for this parameter from 1 to 0.85 decreases the probability that N_{init}/K will be much higher than K (only 18% of the pdf is >1 with this prior vs. 45% if the mean=1) to reflect the fact that the population might not have been at virgin levels at the beginning of the model. This change did not affect conclusions on stock status for any of the six baseline scenarios considered (compare Tables 1 and 8). Convergence diagnostics were good in all cases (Table 8).

Considering an alternative catch series for LCS—The alternative catch series for LCS (Table 2.5 of the DW) was constructed as in the 2002 SEW to compensate for under-reporting of landings during the earliest years of the time series (1981-1994). This change had little impact on results (compare Tables 1 and 9). Convergence diagnostics were good (Table 9).

Changing the value of recreational catch for 1983—The value of recreational catch in 1983 for the LCS, LCS without prohibited species, and sandbar scenarios (Tables 2.2, 2.3, and 2.8, respectively, in the DW report) was very high (mostly as a result of large numbers of sandbar sharks reported in the MRFSS). As was done in the 2002 SEW, this value was modified to the geometric mean value of the 1982 and 1984 recreational catch estimates. The resulting new recreational catch values for 1983 were thus: 380.8 (LCS), 268.0 (LCS without prohibited species), and 44.1 (sandbar). This change had very little effect on results and did not alter the conclusions on stock status with respect to the baseline scenario (compare Tables 1 and 9). Convergence diagnostics were good (Table 9).

Removing one CPUE series at a time from the full model, and fitting CPUE series one at a time

For LCS, the MVT importance function was used for each series removed, except VIMS, which had better convergence diagnostics drawing from the priors. The upper limit of N_{72}/K had to be increased to 1.5 to allow the full model (with all CPUE series included) to run; this was retained in the sensitivities. The status of the population was overfished and overfishing was occurring, as in the full model, unless the series removed was VIMS (removing PLL also resulted in no overfishing; Table 10). When the series were fit one at a time, the priors were the best importance function, and convergence diagnostics were good. Unlike the full model, the individual series fits showed that the population was not overfished nor overfishing was occurring, unless the series fit was either PLL or VIMS, or PCGN or NMFSLLNE (overfishing only; Table 11).

For LCS without prohibited species, convergence diagnostics were good drawing from the priors for all runs, except when removing the PLL series. For this run, the MVT provided better (but not very good) diagnostics. The status of the population was not overfished and overfishing was not occurring, consistent with the full model (Table 12). The runs fitting individual series found the same, except for the runs with the PCGN series (overfishing) and the PLL series (overfished and overfishing; Table 13).

For LCS without prohibited species, blacktip or sandbar, drawing from the priors produced good diagnostics of convergence except for the run with the PLL series removed. Removing one series did not change the assessment of status, which is not overfished, and overfishing is not occurring (Table 14). The runs by individual series were the same, except for the PLL series, which found that the population is overfished, and overfishing is occurring (Table 15).

For sandbar shark, the importance sampling did not converge for the full model run, or any of the runs with one series removed, except if the series removed was LPS. This run had acceptable convergence diagnostics drawing from the priors and found that the population is overfished, and overfishing is occurring (Table 16). Fitting individual series, the only series for which convergence was obtained with adequate diagnostics were BLLOP, NMFSLLSE, CFL, PLL, and VIMS. The VIMS series implied that the population is overfished, and overfishing is occurring; all the others implied no overfishing and that overfishing is not occurring (Table 17).

For blacktip in the Gulf of Mexico, the MVT importance function provided the best diagnostics for all the runs with one series removed, except the BLLOP series. Convergence diagnostics were not very good for PCGN or NMFSLLSE. All the runs with one series removed found that the population was not overfished and overfishing was not occurring, consistent with the full model, although the run with BLLOP removed estimated a value of K about 20 times higher than the other runs (Table 18). For the runs fit to one series at a time, the MVT importance function provided the best diagnostics for all series except BLLOP. Convergence diagnostics were not very good for PCGN or NMFSLLSE. The runs fit to only one series all found the population was not overfished and overfishing was not occurring, except when adding only the PLL series (Table 19).

For blacktip in the Atlantic, drawing from the priors provided the best convergence diagnostics, and diagnostics were good for all the runs removing a series or using only one series. CVs were set to 1 for the BLLOP series because the very large CVs associated with this series could not be fit by the model. All the runs with one series removed found that the population was overfished, and overfishing was occurring, except for the run with PLL removed, which found that K was very high, overfishing was not occurring, and the population was not overfished (Table 20). In the runs by individual series, the DGNOP and CFL series implied that the population was not overfished and overfishing was not occurring, in contrast to the full model. The BLLOP series could not be fit. Fitting to the PLL series only implied that K is very small, and the population is overfished and overfishing is occurring (Table 21).

For blacktip in the Atlantic and Gulf of Mexico combined, good convergence diagnostics were obtained by drawing from the priors for all the runs fitted to only one CPUE series and all the runs removing a series, except when removing DGNOP. This run had better diagnostics with the MVT importance function. All the runs were consistent with the full model, finding that the population is not overfished and overfishing is not occurring (Tables 22 and 23).

4. Discussion

Baseline scenarios for the three LCS groupings considered predicted that the stock status is not overfished nor overfishing is occurring. Removing the species presently designated as prohibited from the LCS complex resulted in more optimistic results as one would expect given that the prohibited species are believed to be less resilient to fishing pressure. Further removing the two main species in the directed shark fisheries (blacktip and sandbar) resulted in even more optimistic results, with depletions of only 20-26% of the virgin level. The method to weight the CPUE data (equal vs. inverse variance) only had a significant effect on the LCS grouping, changing the predictions on stock status to overfished and overfishing occurring. However, convergence diagnostics for the inverse variance method were not as good as those obtained with the equal weighting method.

Individual assessment of sandbar and blacktip stocks resulted in very different predictions. The sandbar shark stock was estimated to be significantly depleted (64-71% of virgin level) and the Gulf of Mexico (GOM) blacktip shark stock to be healthy (depletions of only 8-23% of virgin level). The method to weight the CPUE series did not affect conclusions for the GOM blacktip shark stock, but the model would not converge when using inverse variance weighting for sandbar shark.

The Atlantic (ATL) blacktip shark stock was predicted to be severely depleted when using the BSP model with inverse variance weighting (depletion of 85% of virgin level) and less depleted when using equal weighting (depletion of 60% of virgin level). A completely different outcome was produced by WinBUGS, which predicted a healthy stock (the only case out of the six baseline scenarios considered where the BSP and WinBUGS model predictions differed). Convergence diagnostics were generally better with the BSP model. It must be noted that only four CPUE series (the earliest starting in 1992) were available for the ATL blacktip stock and the magnitude of the catches in the Atlantic is considerably lower than that in the Gulf of Mexico. In contrast, the assessment of a single blacktip shark stock (GOM+ATL) resulted in very consistent results, with all models (BSP with equal and inverse variance weighting and WinBUGS) predicting a healthy status (depletions of 10-16% of virgin level).

All baseline scenarios assumed that the populations were at a virgin level at the beginning of the model (1972 for the three LCS groupings, 1975 for sandbar, and 1981 for blacktip). Little recreational and directed bottom-longline commercial effort is expected to have occurred before the 1970s so this assumption seems reasonable for LCS and sandbar. In contrast, some level of depletion could have occurred for blacktip shark prior to 1981; however, accounting for some depletion in 1981 with respect to virgin levels did not alter conclusions.

Results were largely insensitive to using the higher values of r from the 2002 SEW and to the various assumptions about the level of catches. Removing one CPUE series at a time from those used in the baseline scenarios (with inverse variance weighting) reversed the conclusions on stock status for LCS (VIMS series) and ATL blacktip shark (PLL series), underscoring the influence of these two series on results.

Fitting one CPUE series at a time to each baseline scenario (with inverse variance weighting) had a larger effect on results. Again, the PLL series greatly influenced conclusions for the three LCS groupings and GOM and ATL blacktip shark, whereas the VIMS series affected conclusions on LCS and sandbar shark, the two groups for which this series is available.

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Table 1. BSP model results (SIR algorithm) for various groupings and species using equal weighting and values of r (intrinsic rate of increase) recommended in the Data Workshop report.

	LCS		LCS-PROH		LCS-PROH-SB-BT		Sandbar		Blacktip (GOM)		Blacktip (ATL)	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors		priors		priors		priors	
K	35830	0.50	51056	0.45	31249	0.80	4584	0.53	29425	0.85	5219	2.55
r	0.048	0.47	0.050	0.47	0.048	0.46	0.038	0.41	0.082	0.56	0.070	0.53
MSY	398.5	0.59	613.4	0.63	359.3	0.96	41.3	0.63	574.4	1.12	97.8	3.18
N_{2004}	24148	0.71	39845	0.56	27585	0.88	1418	1.63	25859	0.95	4311	3.05
N_{2004}/K	**0.63**	0.24	**0.74**	0.20	**0.80**	0.20	**0.29**	0.39	**0.77**	0.24	**0.40**	0.69
N_{init}	32713	0.52	45263	0.47	27770	0.82	4050	0.57	26530	0.86	4814	2.58
N_{2004}/N_{init}	0.69	0.22	0.84	0.21	0.91	0.21	0.32	0.36	0.87	0.25	0.44	0.68
C_{2004}/MSY	0.79	0.47	0.57	0.61	0.37	0.87	1.39	0.37	0.52	0.87	0.86	0.62
F_{2004}/F_{MSY}	**0.73**	0.67	**0.45**	0.94	**0.30**	1.28	**2.83**	0.55	**0.46**	1.37	**1.99**	1.00
N_{2004}/N_{MSY}	**1.25**	0.24	**1.47**	0.20	**1.60**	0.20	**0.57**	0.39	**1.55**	0.24	**0.80**	0.69
C_{2004}/repy	0.914	0.38	0.788	0.42	0.653	49.80	1.875	0.88	0.851	4.96	1.337	10.82
N_{MSY}	17915	0.50	25528	0.45	15625	0.80	2292	0.53	14713	0.85	2610	2.55
F_{MSY}	0.024		0.025		0.024		0.019		0.041		0.035	
repy	305.6	0.32	359.3	0.35	121.4	0.59	31.7	0.43	180.8	0.47	23.1	1.33
C_0	423.6	1.00	460.7	1.10	134.8	1.24	95.8	0.98	n/a	n/a	n/a	n/a
Diagnostics												
CW (wt)	0.908		0.511		0.350		3.214		0.282		2.716	
CV (L*prior)	1.540		0.980		1.235		4.349		1.443		4.743	
CV (Wt) / CV (L*p)	0.59		0.52		0.28		0.74		0.20		0.57	
%maxpWt	0.007		0.002		0.001		0.008		0.001		0.035	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 2. Decision analysis tables for various groupings and species corresponding to the results in Table 1. **DRAFT**

LCS

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.72	0	0.93
	TAC=0.5C_{2003}	0.67	0	0.86
	TAC=1C_{2003}	0.62	0	0.75
	Fmsy	0.63	0	0.84
20 -year	TAC=0	0.79	0	0.98
	TAC=0.5C_{2003}	0.71	0	0.90
	TAC=1C_{2003}	0.62	0.01	0.74
	Fmsy	0.64	0	0.87
30 -year	TAC=0	0.85	0	0.99
	TAC=0.5C_{2003}	0.74	0	0.92
	TAC=1C_{2003}	0.61	0.03	0.73
	Fmsy	0.65	0	0.88

LCS-PROHIBITED

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.81	0	0.97
	TAC=0.5C_{2003}	0.78	0	0.95
	TAC=1C_{2003}	0.74	0	0.91
	Fmsy	0.63	0	0.88
20 -year	TAC=0	0.86	0	0.99
	TAC=0.5C_{2003}	0.81	0	0.96
	TAC=1C_{2003}	0.75	0.01	0.91
	Fmsy	0.57	0	0.77
30 -year	TAC=0	0.90	0	1
	TAC=0.5C_{2003}	0.83	0	0.97
	TAC=1C_{2003}	0.75	0.02	0.90
	Fmsy	0.52	0	0.59

LCS-PROHIBITED-BLACKTIP-SANDBAR

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	1.71	0	0.98
	TAC=0.5C_{2003}	1.67	0	0.96
	TAC=1C_{2003}	1.62	0	0.94
	Fmsy	1.55	0	0.96
20 -year	TAC=0	1.79	0	0.99
	TAC=0.5C_{2003}	1.72	0	0.97
	TAC=1C_{2003}	1.64	0.01	0.94
	Fmsy	1.52	0	0.98
30 -year	TAC=0	1.85	0	1
	TAC=0.5C_{2003}	1.75	0	0.98
	TAC=1C_{2003}	1.65	0.01	0.94
	Fmsy	1.50	0	0.98

SANDBAR SHARK

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.36	0.06	0.13
	TAC=0.5C_{2003}	0.29	0.25	0.07
	TAC=1C_{2003}	0.22	0.53	0.04
	Fmsy	0.32	0.11	0.07
20 -year	TAC=0	0.45	0.01	0.32
	TAC=0.5C_{2003}	0.30	0.30	0.10
	TAC=1C_{2003}	0.15	0.70	0.04
	Fmsy	0.36	0.07	0.12
30 -year	TAC=0	0.53	0.01	0.56
	TAC=0.5C_{2003}	0.30	0.34	0.15
	TAC=1C_{2003}	0.11	0.79	0.04
	Fmsy	0.39	0.05	0.20

BLACKTIP SHARK (GOM)

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.86	0	0.96
	TAC=0.5C_{2003}	0.82	0	0.93
	TAC=1C_{2003}	0.78	0.02	0.88
	Fmsy	0.33	0.08	0.03
20 -year	TAC=0	0.91	0	0.99
	TAC=0.5C_{2003}	0.85	0	0.95
	TAC=1C_{2003}	0.78	0.04	0.87
	Fmsy	0.18	0.67	0.01
30 -year	TAC=0	0.94	0	1
	TAC=0.5C_{2003}	0.87	0.01	0.96
	TAC=1C_{2003}	0.77	0.06	0.87
	Fmsy	0.12	0.84	0.01

BLACKTIP SHARK (ATL)

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.52	0.07	0.44
	TAC=0.5C_{2003}	0.34	0.47	0.28
	TAC=1C_{2003}	0.24	0.66	0.23
	Fmsy			
20 -year	TAC=0	0.64	0.02	0.68
	TAC=0.5C_{2003}	0.31	0.56	0.28
	TAC=1C_{2003}	0.21	0.74	0.21
	Fmsy			
30 -year	TAC=0	0.74	0.01	0.83
	TAC=0.5C_{2003}	0.29	0.6	0.29
	TAC=1C_{2003}	0.19	0.76	0.20
	Fmsy			

Table 3. WinBUGS model results (MCMC algorithm) for various groupings and species using equal weighting and values of r (intrinsic rate of increase) recommended in the Data Workshop report.

	LCS		LCS-PROH		LCS-PROH-SB-BT		Sandbar		Blacktip (GOM)		Blacktip (ATL)	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
K	48280	0.46	61580	0.33	47990	0.51	14210	1.11	43640	0.59	24760	1.04
r	0.045	0.09	0.046	0.09	0.043	0.02	0.039	0.02	0.078	0.04	0.078	0.05
MSY	544.7	0.47	700.0	0.34	516.3	0.51	138.5	1.11	852.0	0.59	483.4	1.04
N_{2004}	32190	0.57	43960	0.54	37620	0.78	5513	1.36	41510	0.65	24120	1.09
N_{2004}/K	**0.65**	0.23	**0.69**	0.35	**0.74**	0.46	**0.36**	0.27	**0.92**	0.19	**0.91**	0.22
N_{init}	44418		56025		43594		13276		39080		22197	
N_{2004}/N_{init}	0.72		0.78		0.86		0.42		1.06		1.09	
C_{2004}/MSY	0.54		0.35		0.12		0.36		0.15		0.03	
F_{2004}/F_{MSY}	**0.47**		**0.35**		**0.18**		**0.91**		**0.14**		**0.11**	
N_{2004}/N_{MSY}	**1.33**		**1.43**		**1.57**		**0.78**		**1.90**		**1.95**	
N_{MSY}	24140		30790		23995		7105		21820		12380	
F_{MSY}	0.023		0.023		0.022		0.020		0.039		0.039	
C_0	881.5	0.97	2433	0.57	2135	0.66	766.3	1.13	n/a	n/a	n/a	n/a
N_{init}/K	0.92	0.12	0.91	0.13	0.91	0.13	0.93	0.12	0.90	0.14	0.90	0.14
Diagnostics												
Chain mixing	good		good		good		good		good		good	
Autocorrelations	high		high		high		high		high		high	
Gelman-Rubin	good		good		good		good		good		good	

N_{init} is initial abundance (for the first year of the model)

Table 4. BSP model results (SIR algorithm) for various groupings and species using inverse variance weighting and values of r (intrinsic rate of increase) recommended in the Data Workshop report. Results that alter conclusions derived from the baseline scenario are highlighted in red. Blanks for sandbar shark indicate that importance sampling did not converge.

	LCS		LCS-PROH		LCS-PROH-SB-BT		Sandbar		Blacktip (GOM)		Blacktip (ATL)	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
Importance function	multivariate		priors		priors				multivariate		priors	
K	11813	0.15	54998	0.41	29651	0.83			1093	0.08	2018	3.43
r	0.108	0.32	0.059	0.46	0.056	0.50			1.040	0.10	0.072	0.53
MSY	304.4	0.19	751.7	0.52	363.4	0.91			282.0	0.02	36.7	4.37
N_{2004}	4743	0.17	43617	0.49	25769	0.91			937	0.06	1091	6.27
N_{2004}/K	**0.40**	0.12	**0.77**	0.16	**0.80**	0.18			**0.86**	0.02	**0.15**	1.10
N_{init}	13805	0.20	46910	0.43	25333	0.85			877	0.10	1845	3.50
N_{2004}/N_{init}	0.35	0.13	0.91	0.18	0.94	0.20			1.07	0.06	0.17	1.09
C_{2004}/MSY	0.86	0.25	0.42	0.50	0.31	0.74			0.45	0.02	1.13	0.50
F_{2004}/F_{MSY}	**1.09**	0.31	**0.30**	0.67	**0.23**	0.99			**0.26**	0.04	**5.61**	0.68
N_{2004}/N_{MSY}	**0.81**	0.12	**1.54**	0.16	**1.60**	0.18			**1.72**	0.02	**0.30**	1.10
C_{2004}/repy	0.907	0.26	0.628	0.35	0.555	5.71			0.815	0.10	2.828	2.66
N_{MSY}	5906	0.15	27499	0.41	14826	0.83			546	0.08	1009	3.43
F_{MSY}	0.054		0.029		0.028				0.520		0.036	
repy	289.8	0.20	436.9	0.32	142.5	0.57			156.7	0.11	9.8	1.69
C_0	175.6	0.74	620.5	1.13	178.9	1.49			n/a	n/a	n/a	n/a
Diagnostics												
CW (wt)	6.290		1.238		1.277				18.915		6.887	
CV (L*prior)	5.145		1.022		1.152				20.828		9.401	
CV (Wt) / CV (L*p)	1.22		1.21		1.11				0.91		0.73	
%maxpWt	0.381		0.021		0.099				0.650		0.136	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 5. Decision analysis tables for various groupings and species corresponding to the results in Table 4. **DRAFT**

LCS

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.66	0	0.94
	TAC=0.5C_{2003}	0.53	0	0.65
	TAC=1C_{2003}	0.4	0.01	0.13
	Fmsy	0.4	0	0.12
20 -year	TAC=0	0.83	0	1
	TAC=0.5C_{2003}	0.65	0	0.87
	TAC=1C_{2003}	0.4	0.09	0.26
	Fmsy	0.4	0.02	0.2
30 -year	TAC=0	0.92	0	1
	TAC=0.5C_{2003}	0.72	0	0.93
	TAC=1C_{2003}	0.38	0.2	0.33
	Fmsy	0.4	0.07	0.25

LCS-PROHIBITED

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.85	0	0.99
	TAC=0.5C_{2003}	0.82	0	0.99
	TAC=1C_{2003}	0.79	0	0.98
	Fmsy	0.7	0	0.97
20 -year	TAC=0	0.9	0	1
	TAC=0.5C_{2003}	0.86	0	0.99
	TAC=1C_{2003}	0.81	0	0.99
	Fmsy	0.66	0	0.96
30 -year	TAC=0	0.93	0	1
	TAC=0.5C_{2003}	0.88	0	1
	TAC=1C_{2003}	0.82	0	0.99
	Fmsy	0.63	0	0.91

LCS-PROHIBITED-BLACKTIP-SANDBAR

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.86	0	0.99
	TAC=0.5C_{2003}	0.84	0	0.98
	TAC=1C_{2003}	0.82	0	0.97
	Fmsy	0.62	0	0.90
20 -year	TAC=0	0.91	0	1
	TAC=0.5C_{2003}	0.88	0	0.99
	TAC=1C_{2003}	0.84	0	0.98
	Fmsy	0.52	0	0.60
30 -year	TAC=0	0.94	0	1
	TAC=0.5C_{2003}	0.90	0	1
	TAC=1C_{2003}	0.85	0	0.98
	Fmsy	0.46	0	0.31

SANDBAR SHARK

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0			
	TAC=0.5C_{2003}			
	TAC=1C_{2003}			
	Fmsy			
20 -year	TAC=0			
	TAC=0.5C_{2003}			
	TAC=1C_{2003}			
	Fmsy			
30 -year	TAC=0			
	TAC=0.5C_{2003}			
	TAC=1C_{2003}			
	Fmsy			

BLACKTIP SHARK (GOM)

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	1	0	1
	TAC=0.5C_{2003}	0.94	0	1
	TAC=1C_{2003}	0.86	0	1
	Fmsy	0.58	0	0.95
20 -year	TAC=0	1	0	1
	TAC=0.5C_{2003}	0.94	0	1.00
	TAC=1C_{2003}	0.86	0	1
	Fmsy	0.58	0	0.95
30 -year	TAC=0	1	0	1
	TAC=0.5C_{2003}	0.94	0	1
	TAC=1C_{2003}	0.86	0	1.00
	Fmsy	0.58	0	0.95

BLACKTIP SHARK (ATL)

Horizon	Policy	E(Bfin/K)	P(Bfin<0.2K)	P(Bfin>Bmsy)
10 -year	TAC=0	0.25	0.51	0.06
	TAC=0.5C_{2003}	0.06	0.93	0.05
	TAC=1C_{2003}	0.05	0.95	0.04
	Fmsy			
20 -year	TAC=0	0.38	0.2	0.22
	TAC=0.5C_{2003}	0.06	0.94	0.05
	TAC=1C_{2003}	0.05	0.95	0.04
	Fmsy			
30 -year	TAC=0	0.51	0.07	0.46
	TAC=0.5C_{2003}	0.06	0.94	0.05
	TAC=1C_{2003}	0.05	0.96	0.04
	Fmsy			

Table 6. BSP model (SIR algorithm) and WinBUGS model (MCMC) results for blacktip shark (areas combined). Equal weighting (WM=1) and inverse variance weighting (WM=3) were used for the BSP model.

	BSP WM=1		BSP WM=3		WinBUGS	
	EV	CV	EV	CV	EV	CV
Importance function	priors		priors			
K	37423	0.68	41853	0.61	44000	0.59
r	0.094	0.59	0.092	0.59	0.078	0.04
MSY	782.1	0.88	884.3	0.82	859.3	0.59
N_{2004}	33215	0.74	37536	0.66	41670	0.67
N_{2004}/K	**0.84**	0.14	**0.86**	0.12	**0.90**	0.22
N_{init}	32795	0.70	36611	0.62	37325	
N_{2004}/N_{init}	0.97	0.17	1.00	0.15	1.12	
C_{2004}/MSY	0.33	0.76	0.29	0.78	0.17	
F_{2004}/F_{MSY}	**0.23**	1.04	**0.19**	1.02	**0.20**	
N_{2004}/N_{MSY}	**1.68**	0.14	**1.72**	0.12	**1.89**	
C_{2004}/repy	0.659	1.88	0.645	0.59		
N_{MSY}	18712	0.68	20926	0.61	22000	
F_{MSY}	0.047		0.046		0.039	
repy	255.8	0.39	264.7	0.40		
C_0	n/a		n/a		n/a	
N_{init}/K					0.85	0.15
Diagnostics						
CW (wt)	0.620		0.655			
CV (L*prior)	1.097		1.061			
CV (Wt) / CV (L*p)	0.57		0.62			
%maxpWt	0.009		0.029			
Chain mixing					good	
Autocorrelations					high	
Gelman-Rubin					good	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 7. BSP model results (SIR algorithm) for various groupings and species using equal weighting and values of r (intrinsic rate of increase) from the 2002 SEW.

	LCS		LCS-PROH		LCS-PROH-SB-BT		Sandbar		Blacktip (GOM)		Blacktip (ATL)	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors		priors		priors		priors	
K	24298	0.70	40093	0.63	24000	1.02	3617	0.72	27609	0.91	6100	2.44
r	0.125	0.68	0.141	0.73	0.132	0.75	0.084	0.62	0.145	0.77	0.103	0.72
MSY	613.8	0.96	1228.4	0.98	686.4	1.47	66.4	1.40	939.7	1.40	198.0	3.51
N_{2004}	17494	0.91	34420	0.72	22250	1.09	1131	2.21	25138	0.98	5316	2.79
N_{2004}/K	**0.67**	0.23	**0.81**	0.18	**0.84**	0.19	**0.28**	0.39	**0.81**	0.22	**0.43**	0.70
N_{init}	22399	0.73	35759	0.65	21512	1.04	3211	0.78	24971	0.92	5634	2.46
N_{2004}/N_{init}	0.74	0.23	0.92	0.21	0.95	0.22	0.32	0.37	0.92	0.24	0.47	0.70
C_{2004}/MSY	0.55	0.49	0.35	0.69	0.26	0.90	0.92	0.48	0.39	0.95	0.71	0.74
F_{2004}/F_{MSY}	**0.47**	0.72	**0.26**	1.03	**0.20**	1.34	**1.88**	0.65	**0.33**	1.45	**1.64**	1.10
N_{2004}/N_{MSY}	**1.34**	0.23	**1.62**	0.18	**1.68**	0.19	**0.57**	0.39	**1.63**	0.22	**0.86**	0.70
C_{2004}/repy	0.679	0.33	0.645	0.28	0.594	4.09	1.257	0.60	0.748	16.81	1.150	14.88
N_{MSY}	12149	0.70	20046	0.63	12000	1.02	1808	0.72	13805	0.91	3050	2.44
F_{MSY}	0.063		0.070		0.066		0.042		0.073		0.051	
repy	392.4	0.21	406.6	0.23	115.0	0.41	48.4	0.40	184.4	0.37	26.0	1.09
C_0	339.0	0.96	454.2	1.10	129.8	1.20	87.4	0.94	n/a	n/a	n/a	n/a
Diagnostics												
CW (wt)	1.473		0.424		0.479		4.645		0.301		3.091	
CV (L*prior)	2.077		1.081		1.595		5.877		1.573		5.444	
CV (Wt) / CV (L*p)	0.71		0.39		0.30		0.79		0.19		0.57	
%maxpWt	0.007		0.001		0.001		0.018		0.001		0.007	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 8. BSP model results (SIR algorithm) for various groupings and species using equal weighting and reducing the mean value of N_{init}/K from 1 to 0.85.

	LCS		LCS-PROH		LCS-PROH-SB-BT		Sandbar		Blacktip (GOM)		Blacktip (ATL)	
	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors		priors		priors		priors	
K	35950	0.48	52452	0.44	32328	0.79	4868	0.90	30451	0.83	5032	2.58
r	0.048	0.47	0.050	0.47	0.047	0.45	0.038	0.41	0.082	0.56	0.070	0.53
MSY	391.2	0.55	652.3	0.61	356.4	0.94	43.8	1.01	595.0	1.09	94.0	3.25
N_{2004}	22635	0.72	39578	0.55	27367	0.87	1774	2.35	26045	0.93	3983	3.16
N_{2004}/K	**0.59**	0.26	**0.72**	0.21	**0.77**	0.21	**0.30**	0.44	**0.76**	0.24	**0.37**	0.71
N_{init}	30177	0.52	42173	0.47	25955	0.81	3883	1.02	25088	0.85	4286	2.64
N_{2004}/N_{init}	0.70	0.23	0.90	0.22	0.97	0.22	0.38	0.39	0.93	0.26	0.45	0.70
C_{2004}/MSY	0.79	0.44	0.52	0.59	0.35	0.86	1.39	0.39	0.48	0.85	0.83	0.60
F_{2004}/F_{MSY}	**0.77**	0.65	**0.43**	0.91	**0.29**	1.28	**2.77**	0.59	**0.44**	1.34	**2.04**	0.97
N_{2004}/N_{MSY}	**1.17**	0.26	**1.43**	0.21	**1.54**	0.21	**0.61**	0.44	**1.52**	0.24	**0.75**	0.71
C_{2004}/repy	0.883	0.38	0.690	0.42	0.555	23.93	1.852	7.83	0.630	103.08	1.310	3.38
N_{MSY}	17975	0.48	26226	0.44	16164	0.79	2434	0.90	15225	0.83	2516	2.58
F_{MSY}	0.024		0.025		0.023		0.019		0.041		0.035	
repy	317.5	0.32	410.6	0.35	152.7	0.62	33.1	0.56	216.6	0.52	26.4	1.59
C_0	427.7	1.00	464.4	1.10	136.5	1.23	139.8	1.27	n/a	n/a	n/a	n/a
Diagnostics												
CW (wt)	0.974		0.549		0.397		2.790		0.287		2.839	
CV (L*prior)	1.615		1.010		1.242		3.970		1.425		4.834	
CV (Wt) / CV (L*p)	0.60		0.54		0.32		0.70		0.20		0.59	
%maxpWt	0.006		0.002		0.002		0.005		0.001		0.004	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 9. BSP model results (SIR algorithm) for various groupings and species using equal weighting and different assumptions about catches.

	LCS/Alternative catch		LCS/1983 changed		LCS-PRO/1983 changed		Sandbar/1983 changed	
	EV	CV	EV	CV	EV	CV	EV	CV
Importance function	priors		priors		priors		priors	
K	37742	0.46	35726	0.50	51106	0.45	4197	0.57
r	0.049	0.47	0.048	0.47	0.050	0.47	0.038	0.42
MSY	425.5	0.55	396.7	0.60	632.7	0.63	38.3	0.66
N_{2004}	25110	0.67	24314	0.71	40272	0.56	1373	1.65
N_{2004}/K	**0.62**	0.24	**0.63**	0.24	**0.75**	0.19	**0.30**	0.38
N_{init}	34428	0.49	32663	0.53	45207	0.47	3710	0.61
N_{2004}/N_{init}	0.68	0.22	0.69	0.22	0.85	0.20	0.34	0.35
C_{2004}/MSY	0.73	0.46	0.80	0.47	0.55	0.61	1.51	0.37
F_{2004}/F_{MSY}	**0.67**	0.66	**0.73**	0.68	**0.43**	0.92	**2.90**	0.56
N_{2004}/N_{MSY}	**1.24**	0.24	**1.26**	0.24	**1.49**	0.19	**0.60**	0.38
C_{2004}/repy	0.830	0.37	0.930	0.38	0.779	0.41	1.960	4.14
N_{MSY}	18871	0.46	17863	0.50	25553	0.45	2099	0.57
F_{MSY}	0.024		0.024		0.025		0.019	
repy	334.1	0.31	300.2	0.32	361.7	0.35	30.3	0.43
C_0	430.4	1.01	424.6	1.00	470.6	1.11	96.1	0.98
Diagnostics								
CW (wt)	0.914		0.890		0.549		3.130	
CV (L*prior)	1.517		1.532		0.978		4.233	
CV (Wt) / CV (L*p)	0.60		0.58		0.56		0.74	
%maxpWt	0.005		0.007		0.002		0.001	

N_{init} is initial abundance (for the first year of the model), repy is replacement yield

Table 10. BSP model results (SIR algorithm) for LCS using inverse variance weighting and removing one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red.

	-DGNOP	-PCGN	-ENP	-SCLLR	-BLLOP	-NMFSLLSE	-CFL	-NMFSLLNE	-PLL	-SCLLE	-VIMS
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
Importance function	MVT	MVT	MVT	MVT	MVT	MVT	MVT	MVT	MVT	MVT	priors
K	12743	11591	11095	11964	13463	12541	12403	11938	11126	12070	25794
r	0.089	0.114	0.116	0.105	0.077	0.094	0.096	0.106	0.127	0.105	0.076
MSY	268.9	314.2	305.4	299.5	244.8	279.0	283.1	300.8	336.7	301.0	430.1
N_{2004}	4753	4708	3815	4739	4872	4870	4799	4760	4818	4879	17426
N_{2004}/K	**0.38**	**0.41**	**0.35**	**0.40**	**0.37**	**0.39**	**0.39**	**0.40**	**0.43**	**0.41**	**0.66**
N_{init}	14713	13499	13110	13955	15452	14655	14427	13986	13178	14138	27073
N_{2004}/N_{init}	0.33	0.35	0.29	0.34	0.32	0.34	0.34	0.35	0.37	0.35	0.64
C_{2004}/MSY	0.99	0.83	0.86	0.88	1.10	0.95	0.94	0.87	0.77	0.87	0.63
F_{2004}/F_{MSY}	**1.36**	**1.04**	**1.27**	**1.13**	**1.56**	**1.25**	**1.23**	**1.11**	**0.90**	**1.10**	**0.51**
N_{2004}/N_{MSY}	**0.75**	**0.82**	**0.69**	**0.80**	**0.73**	**0.78**	**0.78**	**0.80**	**0.87**	**0.81**	**1.33**
C_{2004}/repy	1.078	0.875	0.964	0.928	1.209	1.013	1.001	0.921	0.792	0.917	0.763
N_{MSY}	6371	5796	5547	5982	6731	6270	6202	5969	5563	6035	12897
F_{MSY}	0.045	0.057	0.058	0.053	0.038	0.047	0.048	0.053	0.063	0.052	0.038
repy	250.0	300.1	273.5	283.9	225.1	263.1	266.5	285.9	327.4	287.2	352.1
C_0	208.2	171.8	211.2	183.6	229.4	192.1	194.4	182.2	152.4	187.6	478.0
Diagnostics											
CW (wt)	7.277	5.279	6.415	9.079	8.090	6.992	9.019	7.143	5.854	5.762	4.771
CV (L*prior)	7.281	5.426	6.703	7.688	7.274	6.985	8.442	7.285	6.025	5.977	2.299
CV (Wt) / CV (L*p)	1.00	0.97	0.96	1.18	1.11	1.00	1.07	0.98	0.97	0.96	2.08
%maxpWt	0.329	0.251	0.306	0.422	0.234	0.355	0.363	0.217	0.323	0.162	0.582

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 11. BSP model results (SIR algorithm) for LCS using inverse variance weighting and fitting only one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red. The SCLLE series had too few data points to estimate all 4 model parameters.

	+DGNOP	+PCGN	+ENP	+SCLLR	+BLLOP	+NMFSLLSE	+CFL	+NMFSLLNE	+PLL	+SCLLE	+VIMS
	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	priors	priors	priors		priors
K	54725	41296	28495	46600	54610	48911	49522	44416	17553		15244
r	0.053	0.045	0.050	0.047	0.057	0.051	0.049	0.047	0.043		0.051
MSY	695.5	456.1	332.7	539.7	728.0	592.7	590.4	508.0	178.5		181.9
N_{2004}	43810	30160	18803	35706	43492	38052	38727	33406	4761		3867
N_{2004}/K	**0.77**	**0.64**	**0.64**	**0.70**	**0.77**	**0.73**	**0.74**	**0.67**	**0.24**		**0.26**
N_{init}	50868	40160	30418	44790	49710	46354	47201	42814	16956		16478
N_{2004}/N_{init}	0.84	0.66	0.61	0.74	0.85	0.78	0.78	0.70	0.24		0.24
C_{2004}/MSY	0.48	0.87	0.87	0.70	0.45	0.60	0.60	0.77	1.68		1.54
F_{2004}/F_{MSY}	**0.35**	**1.14**	**0.72**	**0.73**	**0.32**	**0.51**	**0.50**	**1.02**	**4.42**		**3.09**
N_{2004}/N_{MSY}	**1.54**	**1.27**	**1.29**	**1.40**	**1.54**	**1.46**	**1.47**	**1.35**	**0.47**		**0.52**
C_{2004}/repy	0.773	1.234	1.032	1.023	0.711	0.881	0.893	1.137	2.655		2.024
N_{MSY}	27362	20648	14247	23300	27305	24456	24761	22208	8776		7622
F_{MSY}	0.027	0.022	0.025	0.024	0.028	0.025	0.025	0.023	0.021		0.025
repy	387.7	276.0	272.4	316.1	416.3	348.2	341.4	301.5	116.1		140.2
C_0	548.3	430.0	429.3	458.5	614.4	499.2	480.0	451.5	377.3		396.0
Diagnostics											
CW (wt)	0.792	0.222	1.818	0.284	1.045	0.501	0.458	0.167	3.049		6.960
CV (L*prior)	1.063	1.272	2.191	1.011	1.093	0.996	1.014	1.053	4.175		6.036
CV (Wt) / CV (L*p)	0.74	0.17	0.83	0.28	0.96	0.50	0.45	0.16	0.73		1.15
%maxpWt	0.018	0.002	0.047	0.004	0.047	0.028	0.003	0.001	0.063		0.266

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 12. BSP model results (SIR algorithm) for LCS without prohibited species using inverse variance weighting and removing one CPUE series at a time.

	-DGNOP	-PCGN	-BLLOP	-NMFSLLSE	-CFL	-NMFSLLNE	-PLL
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	MVT
K	50731	54422	50656	55159	54621	54262	56503
r	0.054	0.061	0.051	0.055	0.055	0.061	0.067
MSY	645.4	764.6	612.8	721.9	710.6	760.6	862.9
N_{2004}	39650	42919	39529	43944	43394	42730	44344
N_{2004}/K	**0.74**	**0.76**	**0.74**	**0.77**	**0.77**	**0.76**	**0.77**
N_{init}	44408	45996	44882	47759	47388	45855	46321
N_{2004}/N_{init}	0.85	0.91	0.84	0.90	0.89	0.91	0.95
C_{2004}/MSY	0.51	0.41	0.56	0.45	0.46	0.41	0.35
F_{2004}/F_{MSY}	**0.39**	**0.29**	**0.44**	**0.32**	**0.33**	**0.29**	**0.24**
N_{2004}/N_{MSY}	**1.49**	**1.53**	**1.48**	**1.54**	**1.53**	**1.52**	**1.53**
C_{2004}/repy	0.724	0.607	0.778	0.670	0.677	0.607	0.533
N_{MSY}	25365	27211	25328	27579	27311	27131	28252
F_{MSY}	0.027	0.031	0.025	0.028	0.028	0.031	0.034
repy	382.4	453.4	360.1	410.6	407.0	452.5	524.1
C_0	496.1	684.3	453.8	539.2	538.7	683.3	953.1
Diagnostics							
CW (wt)	0.693	1.584	0.526	0.898	0.867	1.571	2.694
CV (L*prior)	0.987	1.034	1.004	1.005	0.997	1.031	2.173
CV (Wt) / CV (L*p)	0.70	1.53	0.52	0.89	0.87	1.52	1.24
%maxpWt	0.020	0.090	0.005	0.018	0.006	0.050	0.162

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 13. BSP model results (SIR algorithm) for LCS without prohibited species using inverse variance weighting and fitting only one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red. The NMFSLLNE series had too few data points to estimate all 4 model parameters

	+DGNOP	+PCGN	+BLLOP	+NMFSLLSE	+CFL	+NMFSLLNE	+PLL
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	priors
K	55588	41870	55099	49863	50173		23565
r	0.053	0.045	0.056	0.050	0.050		0.044
MSY	700.6	463.5	723.5	600.9	599.4		242.7
N_{2004}	44330	30334	43742	38617	38970		11521
N_{2004}/K	**0.77**	**0.63**	**0.77**	**0.73**	**0.73**		**0.40**
N_{init}	48671	37604	47615	44131	44532		21093
N_{2004}/N_{init}	0.88	0.70	0.89	0.83	0.83		0.44
C_{2004}/MSY	0.48	0.87	0.45	0.59	0.59		1.36
F_{2004}/F_{MSY}	**0.35**	**1.17**	**0.32**	**0.51**	**0.49**		**2.28**
N_{2004}/N_{MSY}	**1.54**	**1.25**	**1.53**	**1.45**	**1.46**		**0.79**
C_{2004}/repy	0.712	1.167	0.668	0.812	0.811		1.695
N_{MSY}	27794	20935	27549	24932	25086		11782
F_{MSY}	0.026	0.022	0.028	0.025	0.025		0.022
repy	393.4	285.0	415.9	355.9	352.5		182.3
C_0	511.1	398.3	573.4	463.7	449.4		357.6
Diagnostics							
CW (wt)	0.761	0.225	0.995	0.488	0.465		1.750
CV (L*prior)	0.976	1.251	0.983	0.935	0.965		2.682
CV (Wt) / CV (L*p)	0.78	0.18	1.01	0.52	0.48		0.65
%maxpWt	0.022	0.003	0.015	0.020	0.004		0.024

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 14. BSP model results (SIR algorithm) for LCS without prohibited species, blacktip or sandbar using inverse variance weighting and removing one CPUE series at a time.

	-DGNOP	-PCGN	-BLLOP	-NMFSLLSE	-CFL	-NMFSLLNE	-PLL
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors	priors	MVT
K	25060	30535	28908	29897	31803	30765	28617
r	0.055	0.054	0.051	0.056	0.052	0.054	0.069
MSY	299.0	368.9	339.6	364.8	378.8	371.6	388.9
N_{2004}	21517	26685	25275	26024	27968	26908	24182
N_{2004}/K	**0.75**	**0.80**	**0.78**	**0.80**	**0.81**	**0.81**	**0.78**
N_{init}	21923	26287	25426	25593	27601	26480	23486
N_{2004}/N_{init}	0.86	0.94	0.90	0.94	0.95	0.95	0.97
C_{2004}/MSY	0.42	0.31	0.38	0.31	0.31	0.31	0.25
F_{2004}/F_{MSY}	**0.36**	**0.23**	**0.31**	**0.23**	**0.23**	**0.23**	**0.18**
N_{2004}/N_{MSY}	**1.49**	**1.61**	**1.57**	**1.60**	**1.62**	**1.61**	**1.57**
C_{2004}/repy	0.642	0.569	0.663	0.555	0.593	0.574	0.438
N_{MSY}	12530	15267	14454	14948	15902	15383	14309
F_{MSY}	0.028	0.027	0.026	0.028	0.026	0.027	0.034
repy	119.9	138.6	122.8	141.5	135.8	139.1	183.9
C_0	146.4	164.0	139.2	174.8	153.8	163.9	356.6
Diagnostics							
CW (wt)	1.202	0.962	0.536	1.196	0.665	0.910	3.115
CV (L*prior)	1.411	1.145	1.289	1.145	1.137	1.142	2.700
CV (Wt) / CV (L*p)	0.85	0.84	0.42	1.04	0.58	0.80	1.15
%maxpWt	0.058	0.052	0.033	0.074	0.022	0.065	0.248

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 15. BSP model results (SIR algorithm) for LCS without prohibited species, blacktip or sandbar using inverse variance weighting and fitting only one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red. The NMFSLLNE series had too few data points to estimate all 4 model parameters

	+DGNOP	+PCGN	+BLLOP	+NMFSLLSE	+CFL	+NMFSLLNE	+PLL
	EV	EV	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors		priors
K	36541	31173	33998	30474	30874		9118
r	0.049	0.047	0.050	0.046	0.048		0.046
MSY	427.6	355.8	398.4	345.8	353.8		98.7
N_{2004}	32673	27534	30135	26869	27217		5744
N_{2004}/K	**0.84**	**0.79**	**0.83**	**0.78**	**0.79**		**0.37**
N_{init}	32173	27849	29788	27340	27480		8230
N_{2004}/N_{init}	0.97	0.89	0.95	0.87	0.90		0.41
C_{2004}/MSY	0.28	0.40	0.30	0.44	0.39		1.20
F_{2004}/F_{MSY}	**0.20**	**0.38**	**0.22**	**0.49**	**0.35**		**2.39**
N_{2004}/N_{MSY}	**1.68**	**1.58**	**1.65**	**1.55**	**1.58**		**0.74**
C_{2004}/repy	0.633	0.746	0.622	0.808	0.683		1.665
N_{MSY}	18271	15586	16999	15237	15437		4559
F_{MSY}	0.024	0.023	0.025	0.023	0.024		0.023
repy	135.0	117.0	134.6	112.5	119.1		50.0
C_0	141.2	129.8	149.8	126.1	133.6		100.2
Diagnostics							
CW (wt)	0.502	0.237	0.562	0.157	0.294		3.003
CV (L*prior)	1.060	1.253	1.094	1.338	1.232		4.121
CV (Wt) / CV (L*p)	0.47	0.19	0.51	0.12	0.24		0.73
%maxpWt	0.017	0.004	0.038	0.002	0.003		0.101

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 16. BSP model results (SIR algorithm) for sandbar shark using inverse variance weighting and removing one CPUE series at a time. Blanks indicate that importance sampling did not converge.

	-LPS	-BLLOP	-NMFSLLSE	-DBAY	-CFL	-NMFSLLNE	-PLL	-VIMS
	EV	EV	EV	EV	EV	EV	EV	EV
Importance function	priors							
K	4074							
r	0.052							
MSY	49.6							
N_{2004}	1388							
N_{2004}/K	**0.34**							
N_{init}	3778							
N_{2004}/N_{init}	0.37							
C_{2004}/MSY	1.10							
F_{2004}/F_{MSY}	**1.65**							
N_{2004}/N_{MSY}	**0.69**							
$C_{2004}/repy$	1.241							
N_{MSY}	2037							
F_{MSY}	0.026							
repy	44.3							
C_0	86.2							
Diagnostics								
CW (wt)	8.084							
CV (L*prior)	6.567							
CV (Wt) / CV (L*p)	1.23							
%maxpWt	0.480							

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 17. BSP model results (SIR algorithm) for sandbar shark using inverse variance weighting and fitting only one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red. The DBAY and NMFSLLNE series had too few data points to estimate all 4 model parameters. The mode could not be estimated for the LPS series.

	+LPS	+BLLOP	+NMFSLLSE	+DBAY	+CFL	+NMFSLLNE	+PLL	+VIMS
	EV	EV	EV	EV	EV	EV	EV	EV
Importance function		priors	priors		priors		priors	priors
K		35665	29438		32424		31611	4215
r		0.041	0.040		0.040		0.040	0.039
MSY		356.5	287.4		318.7		311.0	39.2
N_{2004}		31661	25769		28675		27827	1213
N_{2004}/K		**0.83**	**0.77**		**0.80**		**0.79**	**0.29**
N_{init}		31602	26469		29133		28276	3797
N_{2004}/N_{init}		0.95	0.86		0.90		0.89	0.32
C_{2004}/MSY		0.28	0.43		0.36		0.38	1.41
F_{2004}/F_{MSY}		**0.20**	**0.43**		**0.30**		**0.37**	**2.51**
N_{2004}/N_{MSY}		**1.66**	**1.54**		**1.61**		**1.58**	**0.58**
C_{2004}/repy		0.720	0.811		0.814		0.814	1.735
N_{MSY}		17832	14719		16212		15805	2107
F_{MSY}		0.021	0.020		0.020		0.020	0.019
repy		122.2	101.8		108.6		108.5	32.3
C_0		128.8	121.0		122.3		123.7	79.6
Diagnostics								
CW (wt)		0.462	0.210		0.300		0.248	5.251
CV (L*prior)		1.136	1.399		1.261		1.236	6.482
CV (Wt) / CV (L*p)		0.41	0.15		0.24		0.20	0.81
%maxpWt		0.004	0.002		0.002		0.003	0.176

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 18. BSP model results (SIR algorithm) for blacktip shark (GOM) using inverse variance weighting and removing one CPUE series at a time.

	-PCGN	-BLLOP	-NMFSLLSE	-CFL	-PLL
	EV	EV	EV	EV	EV
Importance function	MVT	priors	MVT	MVT	MVT
K	1061	26217	1124	1093	1071
r	1.078	0.080	1.004	1.040	1.066
MSY	284.0	508.8	279.9	281.9	283.5
N_{2004}	913	22599	957	936	923
N_{2004}/K	**0.86**	**0.71**	**0.85**	**0.86**	**0.86**
N_{init}	849	23649	907	879	860
N_{2004}/N_{init}	1.08	0.80	1.06	1.07	1.08
C_{2004}/MSY	0.44	0.64	0.45	0.45	0.45
F_{2004}/F_{MSY}	**0.26**	**0.81**	**0.26**	**0.26**	**0.26**
N_{2004}/N_{MSY}	**1.72**	**1.43**	**1.71**	**1.72**	**1.73**
C_{2004}/repy	0.824	0.998	0.787	0.806	0.840
N_{MSY}	530	13108	562	546	536
F_{MSY}	0.539	0.040	0.502	0.520	0.533
repy	154.9	166.7	162.8	158.7	151.7
C_0	215.4	218.2	229.7	223.2	226.4
Diagnostics					
CW (wt)	26.181	0.358	11.542	11.086	14.556
CV (L*prior)	27.292	1.699	9.367	11.179	17.732
CV (Wt) / CV (L*p)	0.96	0.21	1.23	0.99	0.82
%maxpWt	2.636	0.011	1.423	0.443	0.465

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 19. BSP model results (SIR algorithm) for blacktip shark (GOM) using inverse variance weighting and fitting one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red.

	+PCGN	+BLLOP	+NMFSLLSE	+CFL	+PLL
	EV	EV	EV	EV	EV
Importance function	priors	MVT	priors	priors	priors
K	32443	1070	32896	32798	4729
r	0.080	1.066	0.086	0.084	0.067
MSY	636.2	283.4	658.1	653.5	74.5
N_{2004}	28816	920	29295	29195	175
N_{2004}/K	**0.80**	**0.86**	**0.81**	**0.81**	**0.03**
N_{init}	29209	858	29298	29284	4099
N_{2004}/N_{init}	0.90	1.08	0.93	0.92	0.04
C_{2004}/MSY	0.48	0.45	0.42	0.43	1.98
F_{2004}/F_{MSY}	**0.44**	**0.26**	**0.35**	**0.37**	**37.31**
N_{2004}/N_{MSY}	**1.59**	**1.72**	**1.63**	**1.62**	**0.07**
C_{2004}/repy	0.831	0.810	0.776	0.784	9.786
N_{MSY}	16222	535	16448	16399	2364
F_{MSY}	0.040	0.533	0.043	0.042	0.033
repy	186.4	157.7	197.4	195.1	16.1
C_0	218.5	219.7	217.9	218.4	229.3
Diagnostics					
CW (wt)	0.208	23.457	0.318	0.284	10.158
CV (L*prior)	1.295	27.814	1.166	1.181	13.137
CV (Wt) / CV (L*p)	0.16	0.84	0.27	0.24	0.77
%maxpWt	0.001	1.600	0.012	0.004	0.145

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 20. BSP model results (SIR algorithm) for blacktip shark (ATL) using inverse variance weighting and removing one CPUE series at a time. All CVs for BLLOP series were set equal to 1.
Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red.

	-DGNOP	-BLLOP	-CFL	-PLL
	EV	EV	EV	EV
Importance function	priors	priors	priors	priors
K	982	3350	1109	29084
r	0.096	0.072	0.066	0.080
MSY	21.4	62.9	17.5	582.3
N_{2004}	115	2416	159	27832
N_{2004}/K	**0.10**	**0.21**	**0.09**	**0.91**
N_{init}	888	3076	999	26470
N_{2004}/N_{init}	0.11	0.23	0.10	1.01
C_{2004}/MSY	1.01	1.07	1.26	0.12
F_{2004}/F_{MSY}	**6.16**	**4.85**	**7.73**	**0.09**
N_{2004}/N_{MSY}	**0.20**	**0.42**	**0.19**	**1.83**
C_{2004}/repy	2.923	2.524	3.659	0.327
N_{MSY}	491	1675	555	14542
F_{MSY}	0.048	0.036	0.033	0.040
repy	8.1	13.3	6.1	70.9
C_0	52.8	52.2	50.5	52.6
Diagnostics				
CW (wt)	11.290	5.978	8.217	0.485
CV (L*prior)	10.562	8.647	10.950	1.331
CV (Wt) / CV (L*p)	1.07	0.69	0.75	0.36
%maxpWt	0.499	0.131	0.158	0.008

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 21. BSP model results (SIR algorithm) for blacktip shark (ATL) using inverse variance weighting and fitting only one CPUE series at a time. Results that alter conclusions derived from the full model (all CPUE series included) are highlighted in red. The mode could not be estimated for the BLLOP series.

	+DGNOP	+BLLOP	+CFL	+PLL
	EV	EV	EV	EV
Importance function	priors		priors	priors
K	29435		21282	998
r	0.079		0.085	0.079
MSY	589.0		419.2	18.3
N_{2004}	28213		20096	83
N_{2004}/K	**0.91**		**0.85**	**0.08**
N_{init}	26939		19065	901
N_{2004}/N_{init}	1.01		0.96	0.09
C_{2004}/MSY	0.13		0.20	1.14
F_{2004}/F_{MSY}	**0.10**		**0.17**	**8.39**
N_{2004}/N_{MSY}	**1.83**		**1.70**	**0.16**
C_{2004}/repy	0.338		0.488	3.752
N_{MSY}	14718		10641	499
F_{MSY}	0.039		0.042	0.039
repy	68.7		65.9	6.1
C_0	52.6		52.8	49.6
Diagnostics				
CW (wt)	0.503		0.327	9.087
CV (L*prior)	1.339		1.581	11.249
CV (Wt) / CV (L*p)	0.38		0.21	0.81
%maxpWt	0.005		0.038	0.425

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 22. BSP model results (SIR algorithm) for blacktip shark (areas combined) using inverse variance weighting and removing one CPUE series at a time.

	-DGNOP	-PCGN	-BLLOP	-NMFSLLSE	-CFL
	EV	EV	EV	EV	EV
Importance function	MVT	priors	priors	priors	priors
K	30877	41403	43103	42281	42281
r	0.128	0.093	0.085	0.087	0.087
MSY	698.6	876.0	882.8	873.9	873.9
N_{2004}	27196	37095	38790	37968	37968
N_{2004}/K	**0.81**	**0.86**	**0.86**	**0.86**	**0.86**
N_{init}	26693	36157	38529	37512	37512
N_{2004}/N_{init}	0.95	1.00	0.97	0.98	0.98
C_{2004}/MSY	0.35	0.29	0.31	0.31	0.31
F_{2004}/F_{MSY}	**0.25**	**0.19**	**0.21**	**0.20**	**0.20**
N_{2004}/N_{MSY}	**1.62**	**1.72**	**1.72**	**1.72**	**1.72**
C_{2004}/repy	0.627	0.643	0.700	0.679	0.679
N_{MSY}	15438	20701	21552	21141	21141
F_{MSY}	0.064	0.046	0.042	0.044	0.044
repy	260.8	265.2	248.4	253.7	253.7
C_0	258.4	260.1	260.9	261.0	261.0
Diagnostics					
CW (wt)	3.483	0.667	0.547	0.577	0.558
CV (L*prior)	3.425	1.058	1.050	1.056	1.057
CV (Wt) / CV (L*p)	1.02	0.63	0.52	0.55	0.53
%maxpWt	0.233	0.035	0.008	0.015	0.010

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

Table 23. BSP model results (SIR algorithm) for blacktip shark (areas combined) using inverse variance weighting and fitting only one CPUE series at a time.

	+DGNOP	+PCGN	+BLLOP	+NMFSLLSE	+CFL
	EV	EV	EV	EV	EV
Importance function	priors	priors	priors	priors	priors
K	39833	34183	33094	34828	35027
r	0.077	0.081	0.083	0.087	0.089
MSY	780.4	671.1	657.3	703.0	712.5
N_{2004}	35474	29870	28825	30590	30818
N_{2004}/K	**0.81**	**0.78**	**0.78**	**0.80**	**0.81**
N_{init}	36315	30774	29663	31011	31110
N_{2004}/N_{init}	0.90	0.88	0.88	0.91	0.92
C_{2004}/MSY	0.46	0.49	0.49	0.42	0.41
F_{2004}/F_{MSY}	**0.46**	**0.45**	**0.47**	**0.35**	**0.32**
N_{2004}/N_{MSY}	**1.63**	**1.57**	**1.55**	**1.61**	**1.62**
C_{2004}/repy	0.866	0.820	0.818	0.748	0.729
N_{MSY}	19916	17091	16547	17414	17513
F_{MSY}	0.038	0.040	0.042	0.043	0.044
repy	218.3	220.0	221.8	234.4	238.1
C_0	262.1	261.8	262.5	261.3	262.5
Diagnostics					
CW (wt)	0.405	0.212	0.213	0.342	0.418
CV (L*prior)	1.183	1.258	1.230	1.124	1.112
CV (Wt) / CV (L*p)	0.34	0.17	0.17	0.30	0.38
%maxpWt	0.004	0.002	0.005	0.022	0.014

N_{init} is initial abundance (for the first year of the model), repy is replacement yield, MVT is multivariate t

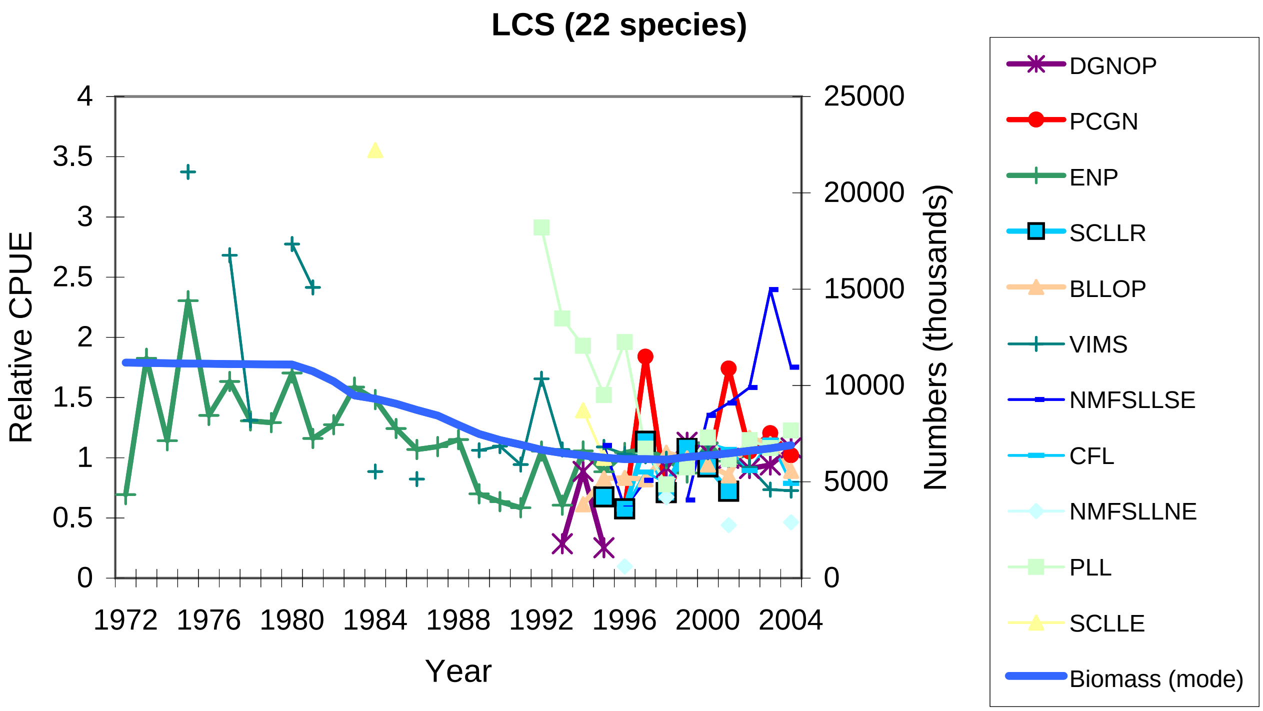


Figure 1. Predicted abundance trend of the BSP model fittted to the catch and CPUE data for LCS. CPUE series shown are scaled (divided by the mean of the overlapping years among all series).

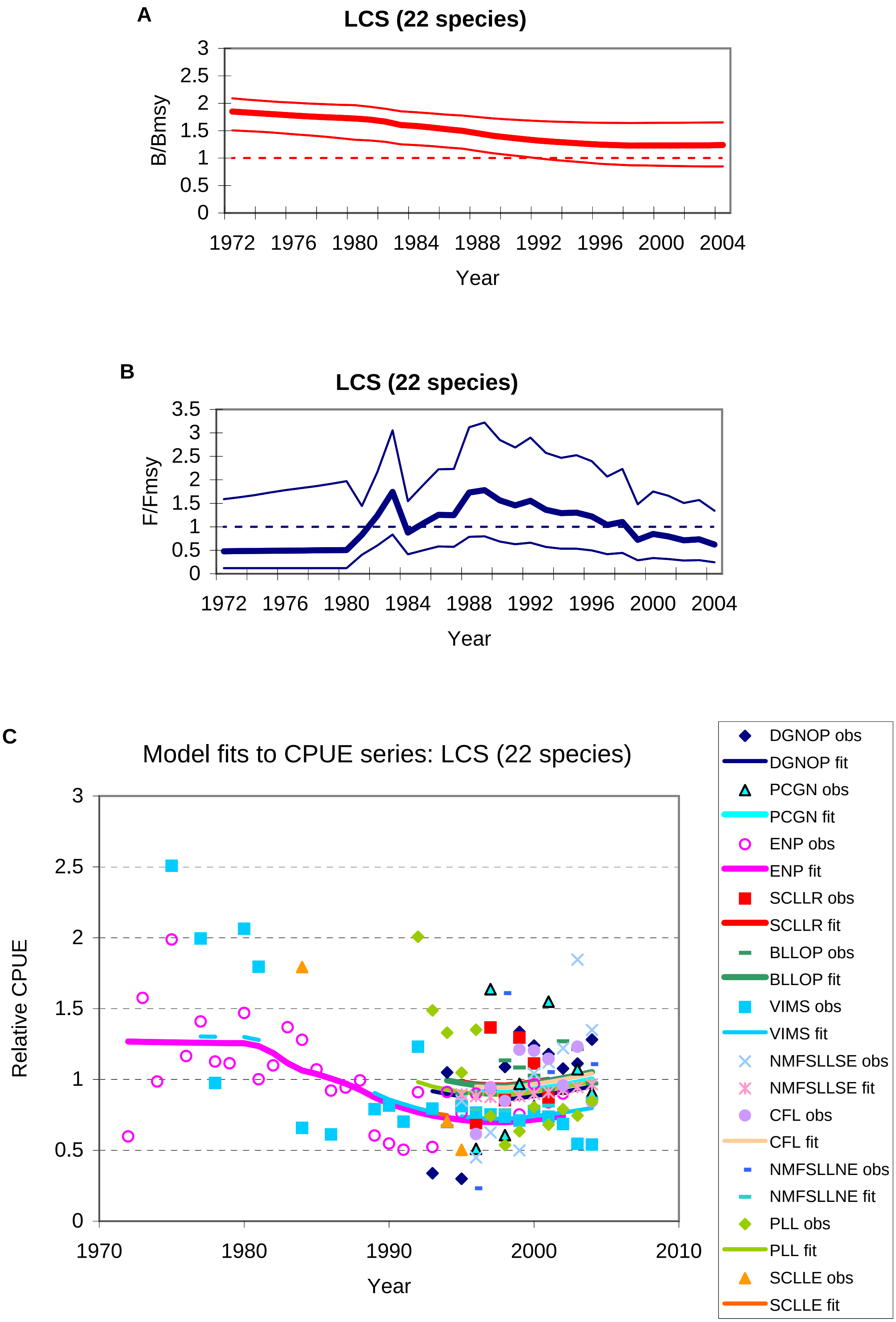


Figure 2. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for LCS with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Model fits to the individual CPUE series are shown in (C).

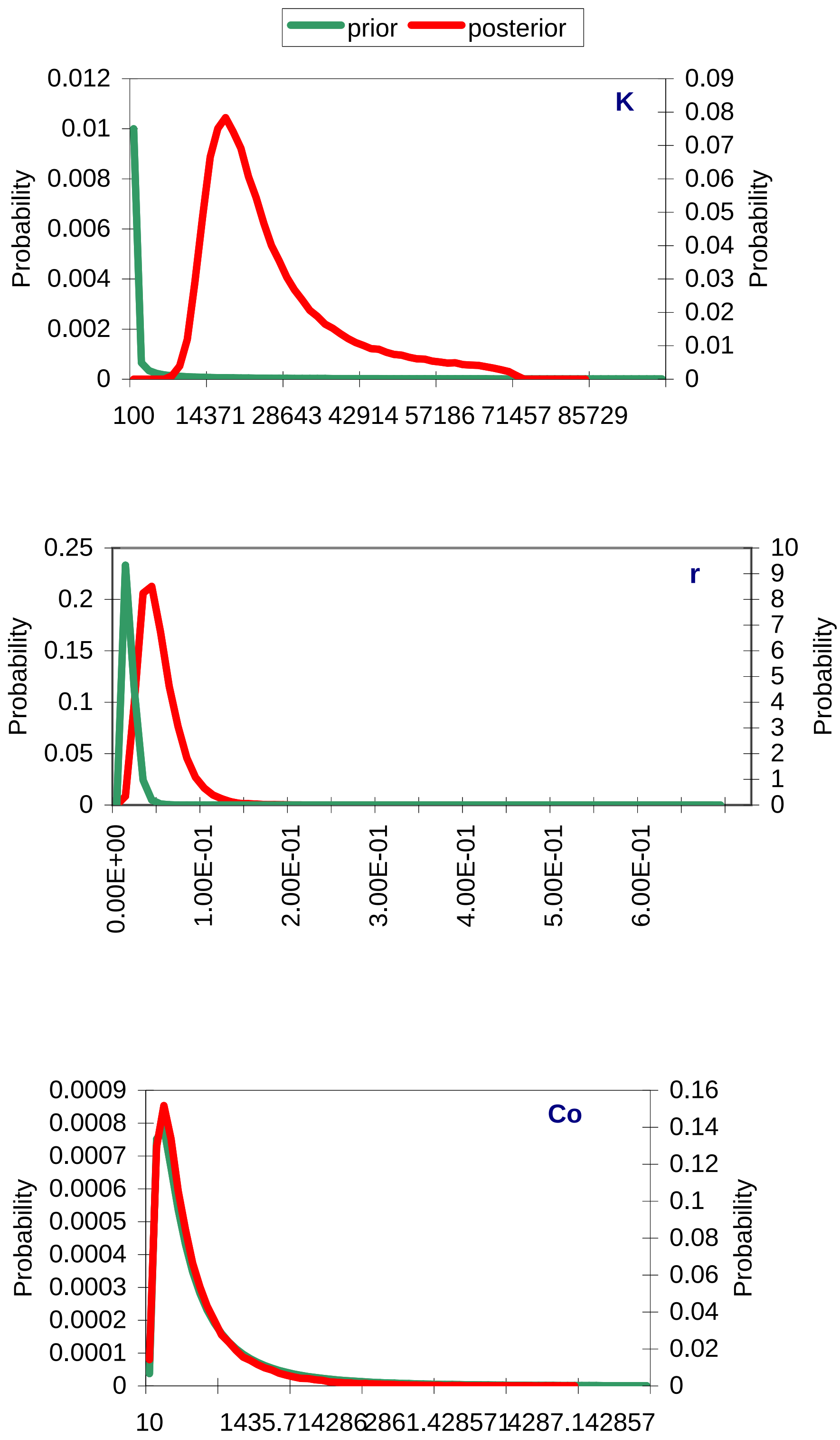


Figure 3. Prior (green) and posterior (red) probability distributions for K, r and Co for LCS from the BSP model.

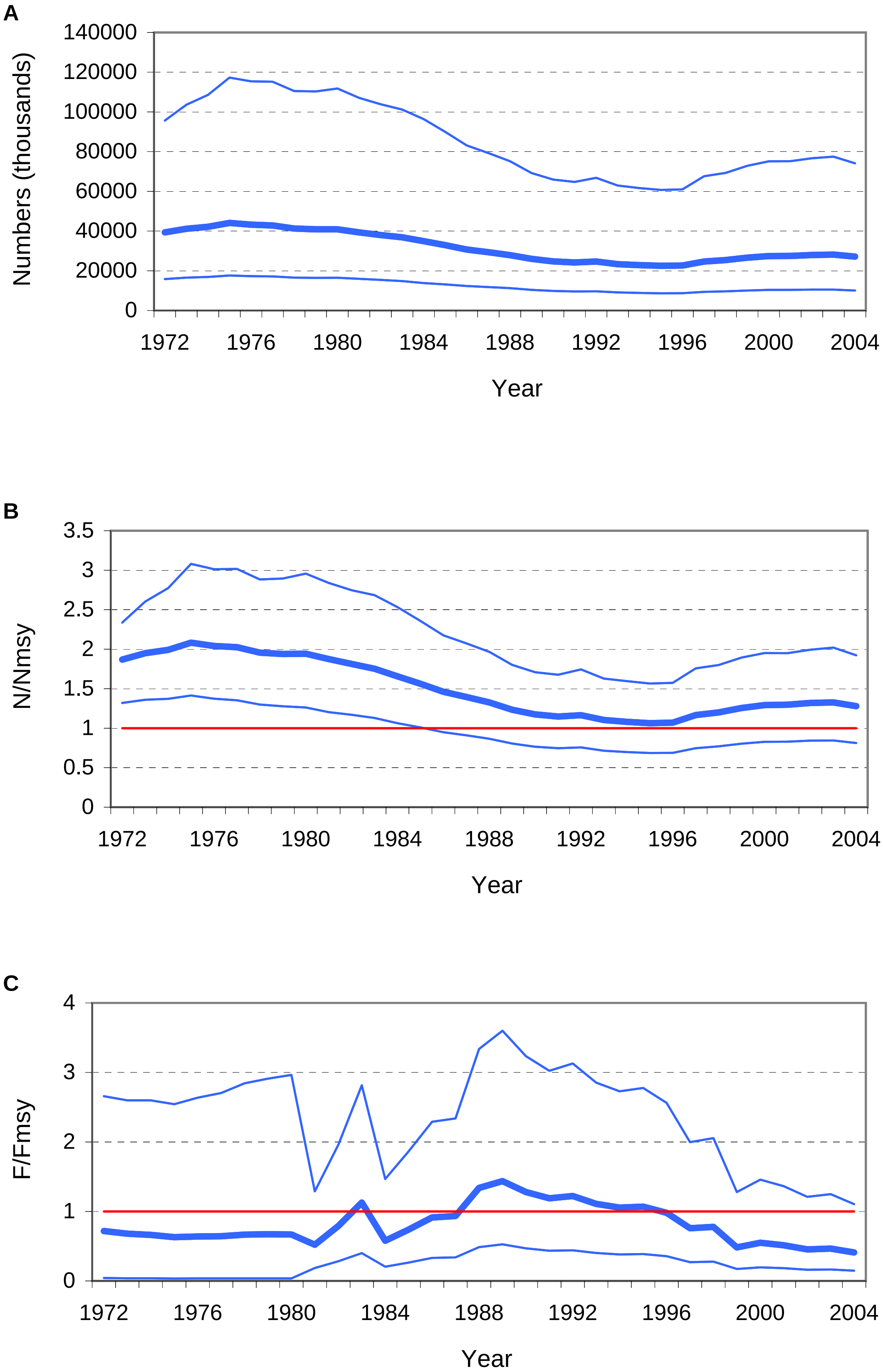


Figure 4. Predicted biomass trend (A), and relative abundance (B) and fishing mortality rate (C) trajectories for LCS with the WinBUGS model. Values shown are medians with 95% probability intervals; horizontal lines at 1 denote MSY levels.

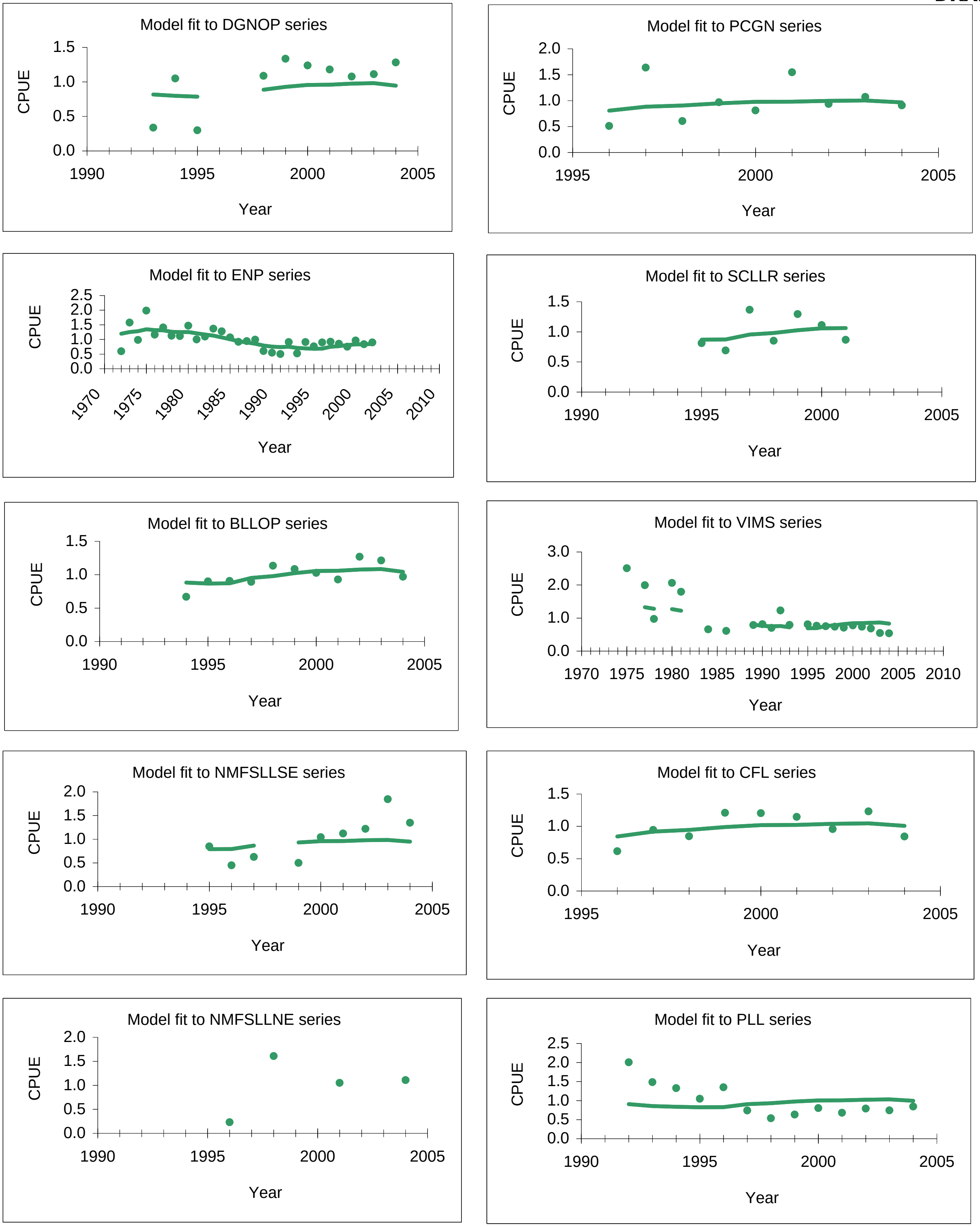


Figure 5. WinBUGS model fits to the individual CPUE series for LCS.

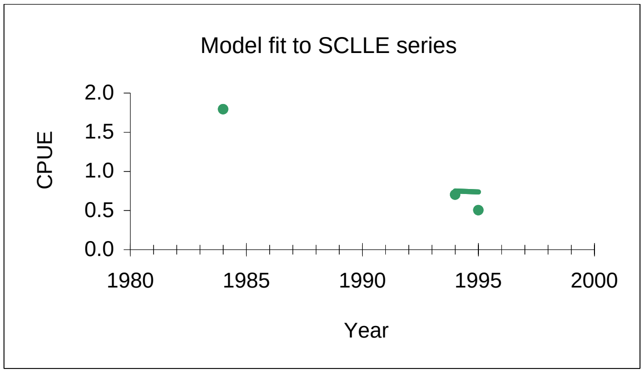


Figure 5 (continued). WinBUGS model fits to the individual CPUE series for LCS.

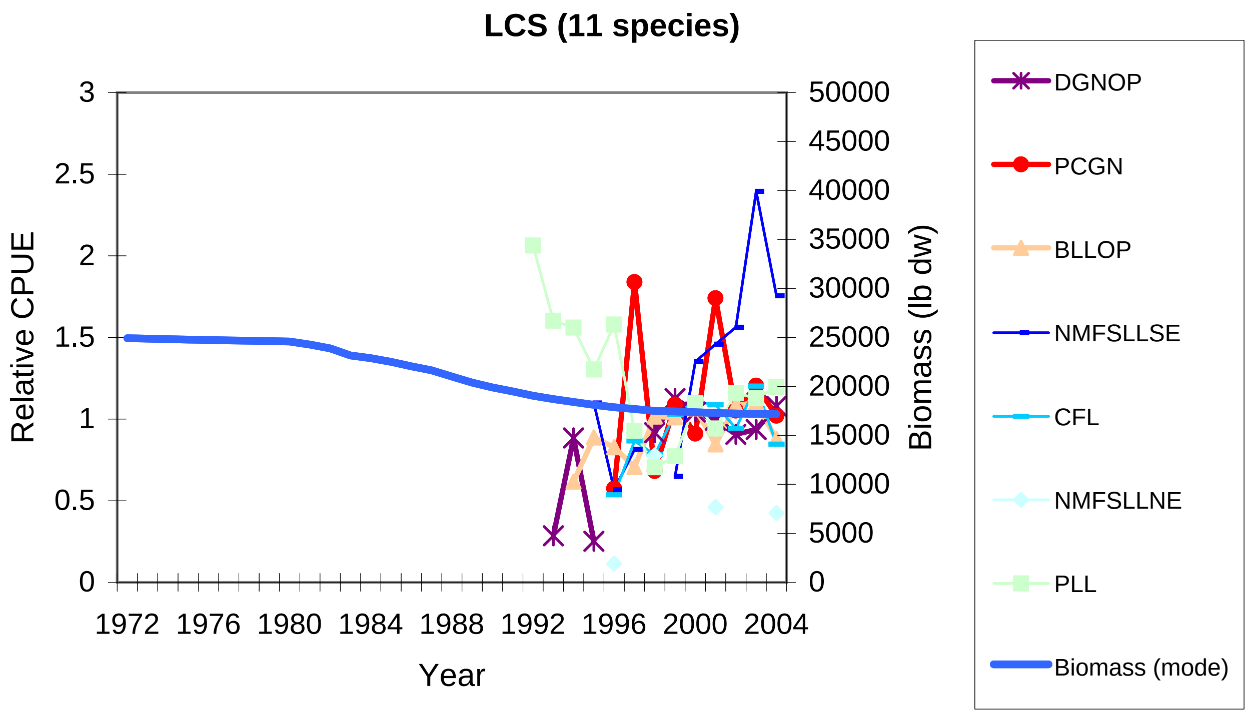


Figure 6. Predicted abundance trend of the BSP model fittted to the catch and CPUE data for LCS without prohibited species. CPUE series shown are scaled (divided by the mean of the overlapping years among all series).

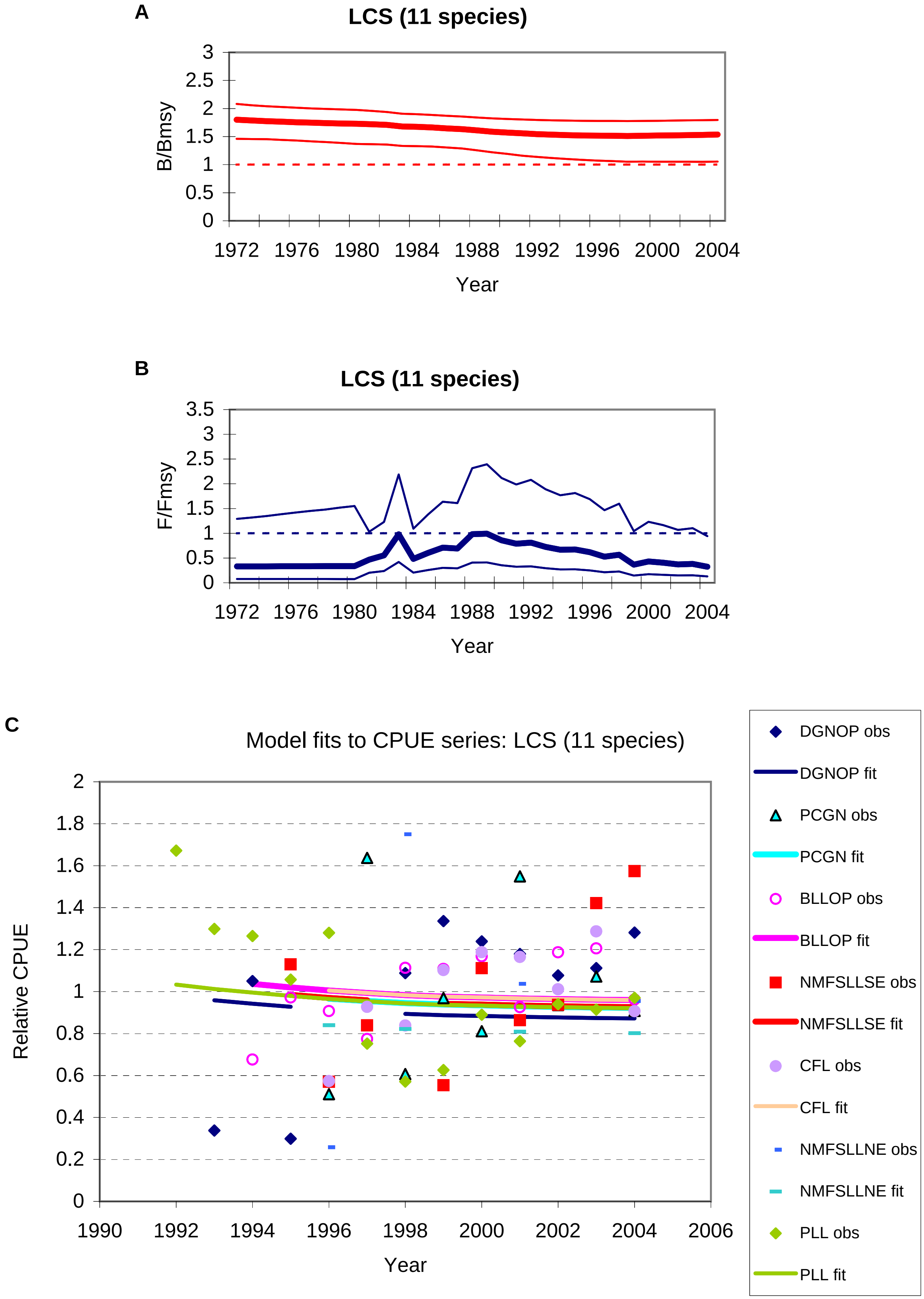


Figure 7. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for LCS without prohibited species with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Model fits to the individual CPUE series are shown in (C).

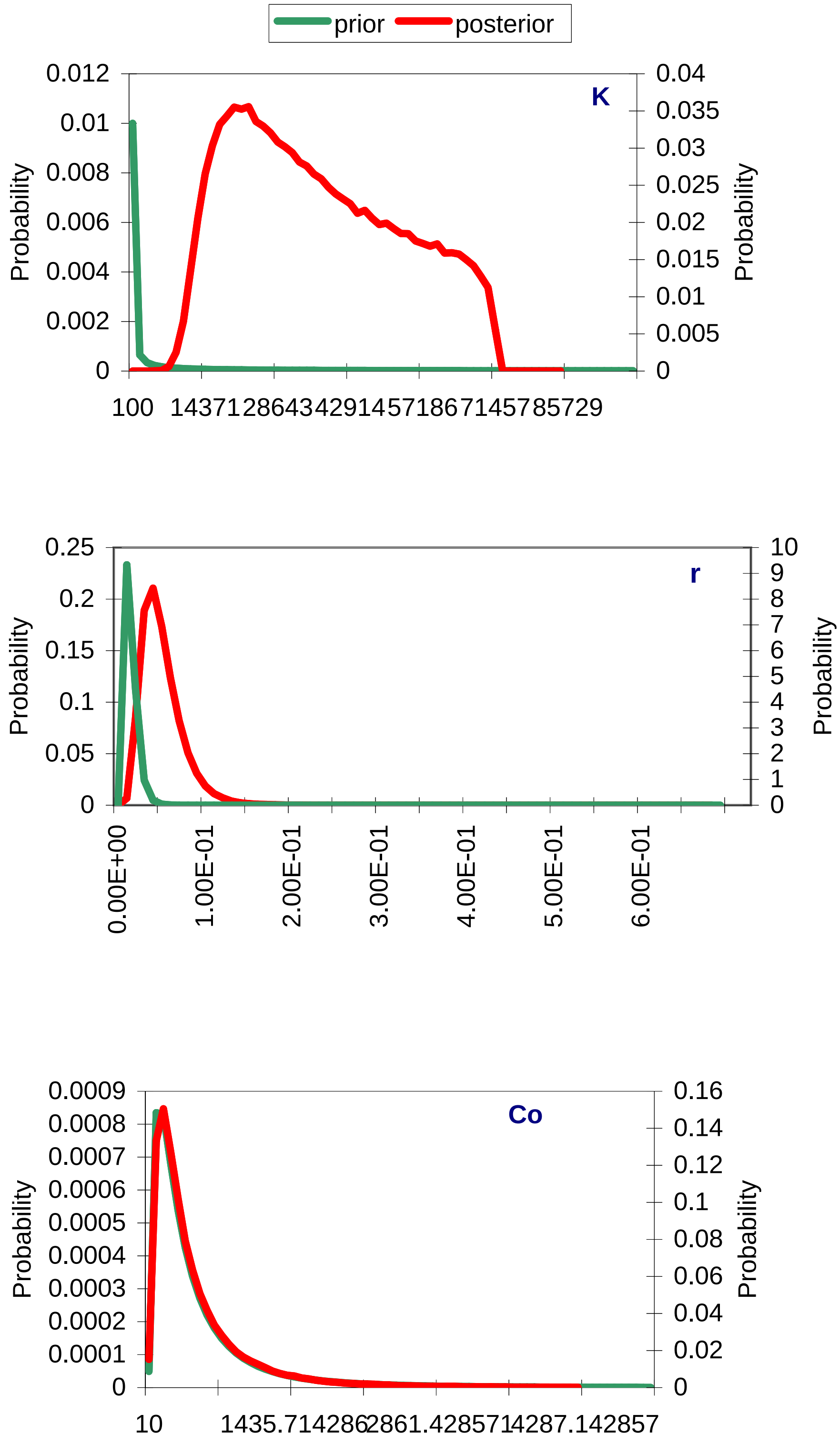


Figure 8. Prior (green) and posterior (red) probability distributions for K, r and Co for LCS without prohibited species from the BSP model.

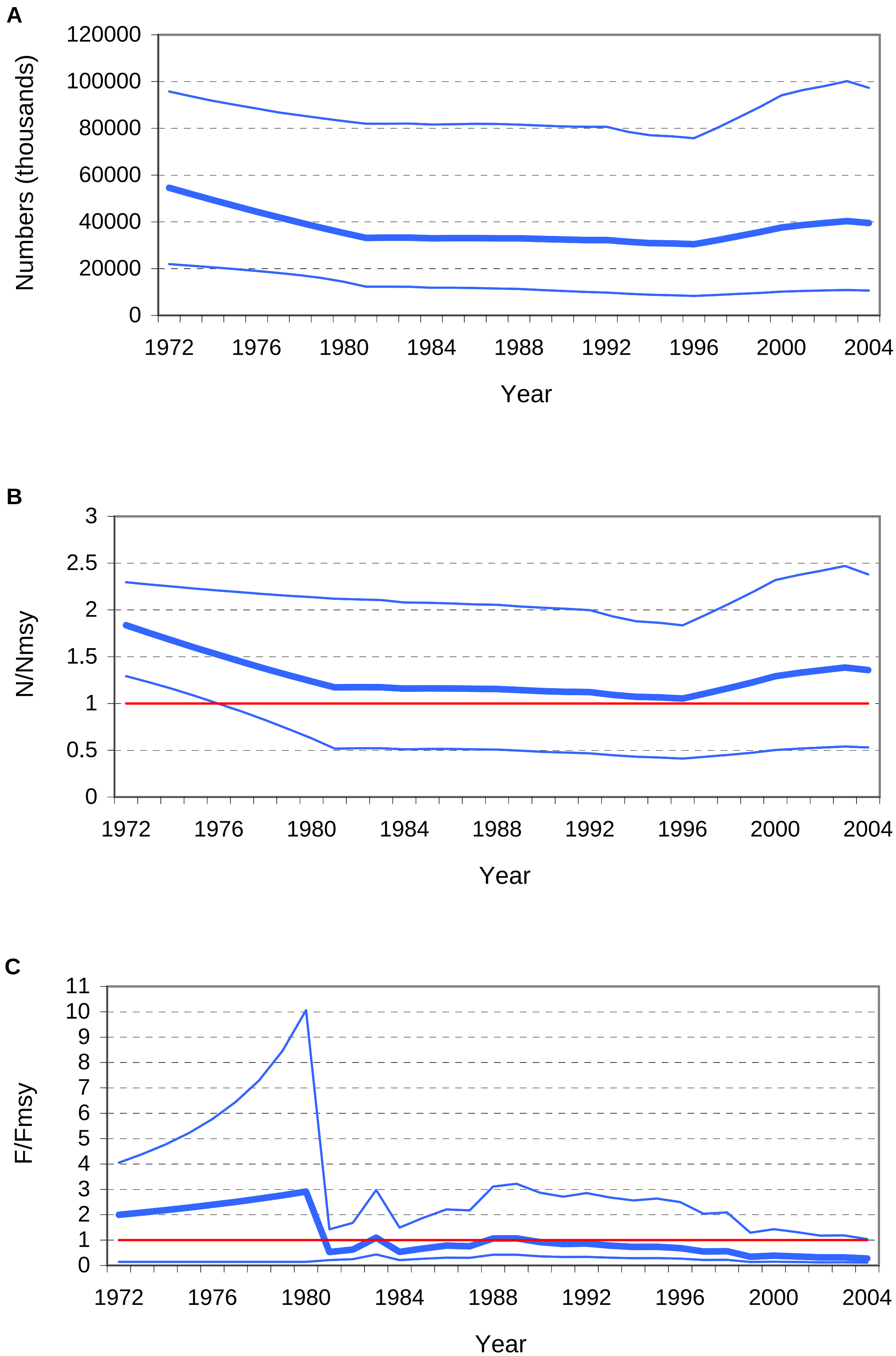


Figure 9. Predicted biomass trend (A), and relative abundance (B) and fishing mortality rate (C) trajectories for LCS without prohibited species with the WinBUGS model. Values shown are medians with 95% probability intervals; horizontal lines at 1 denote MSY levels.

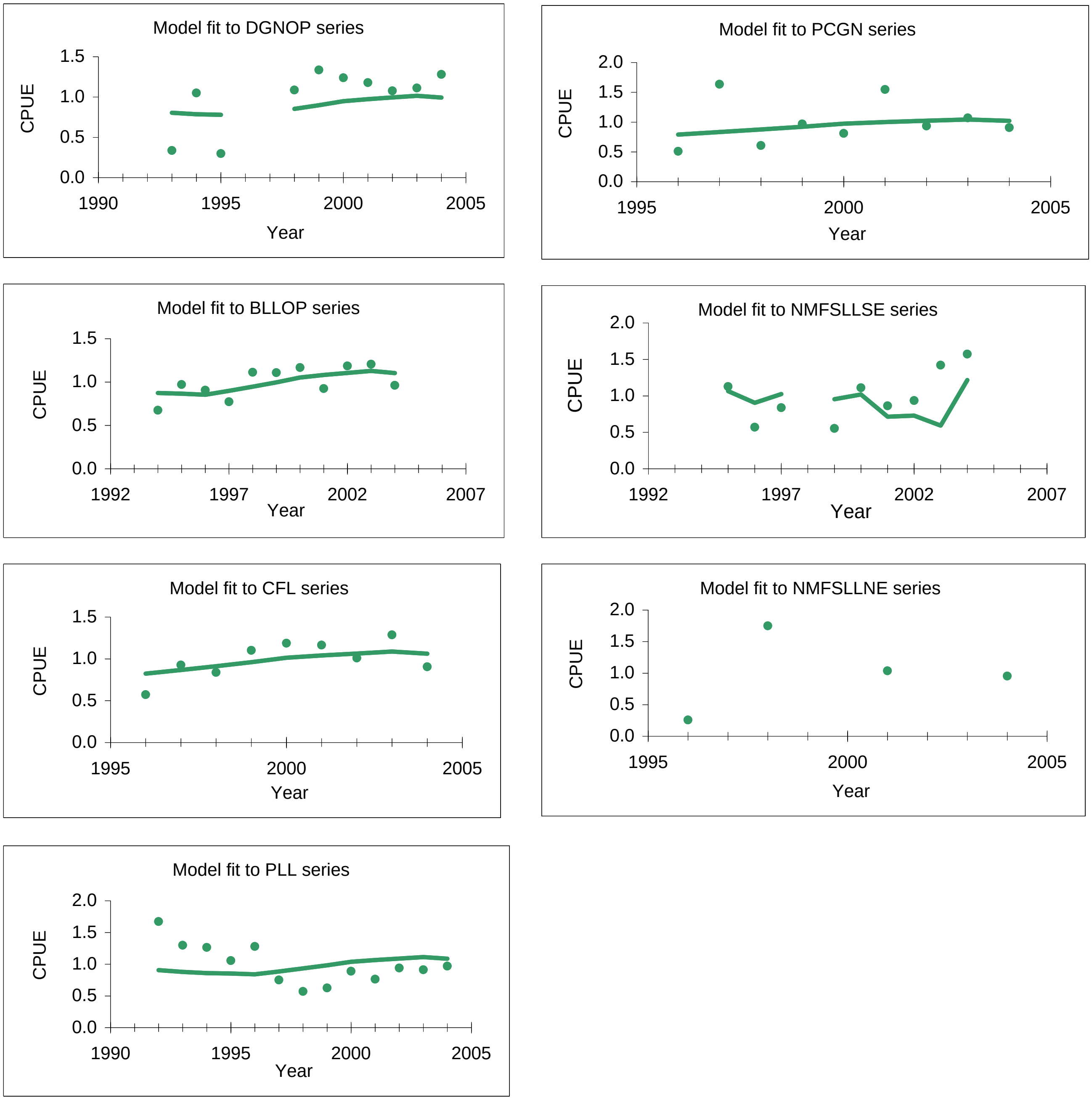


Figure 10. WinBUGS model fits to the individual CPUE series for LCS without prohibited species.

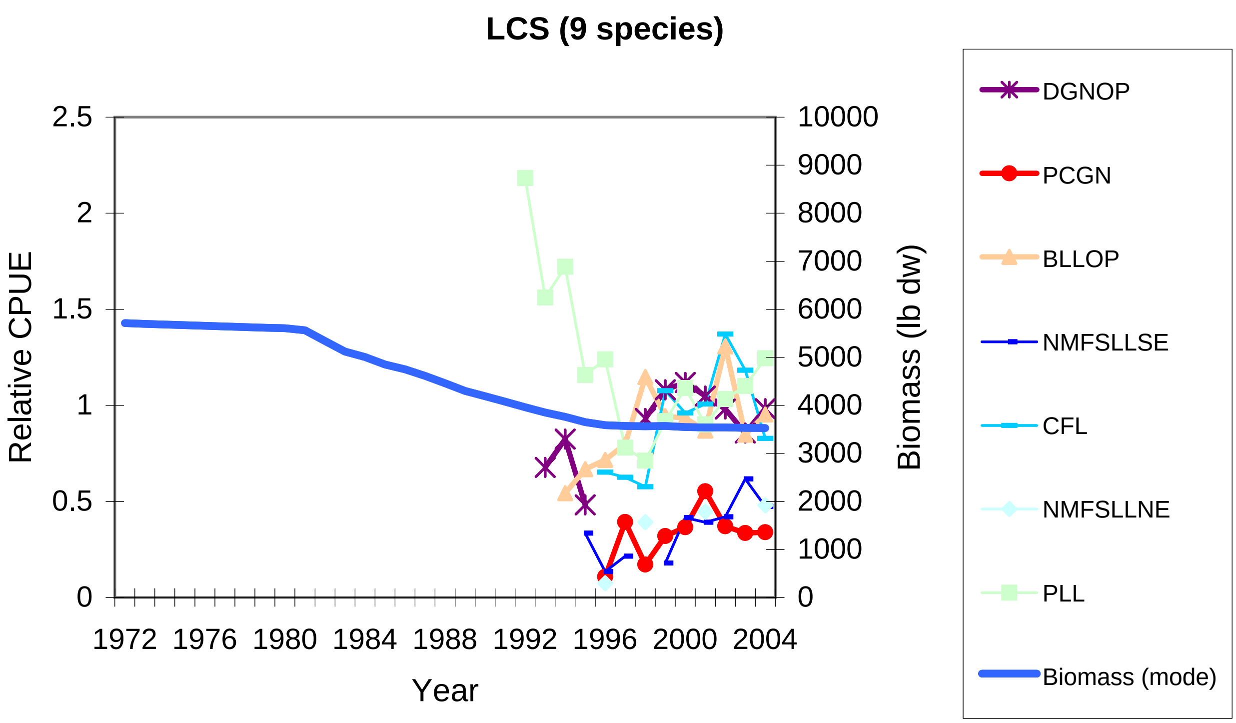
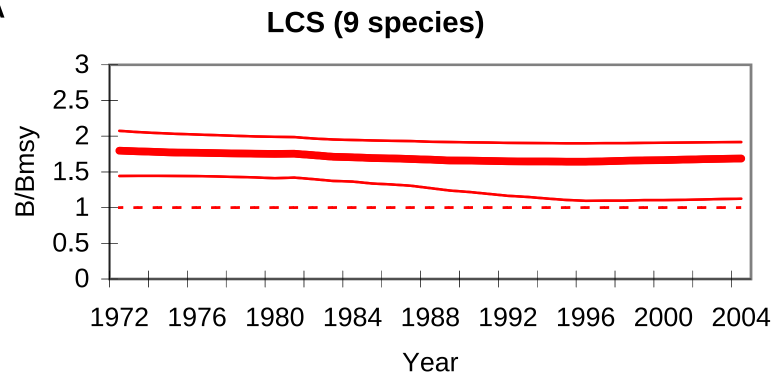
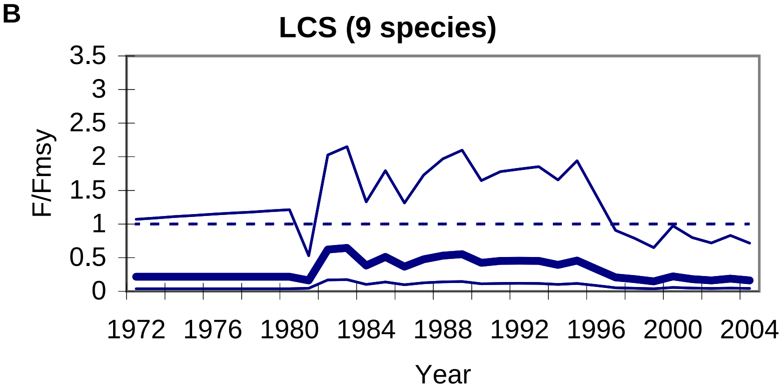


Figure 11. Predicted abundance trend of the BSP model fittted to the catch and CPUE data for LCS without prohibited species, blacktip, or sandbar. CPUE series shown are scaled (divided by the mean of the overlapping years among all series).

A



B



C

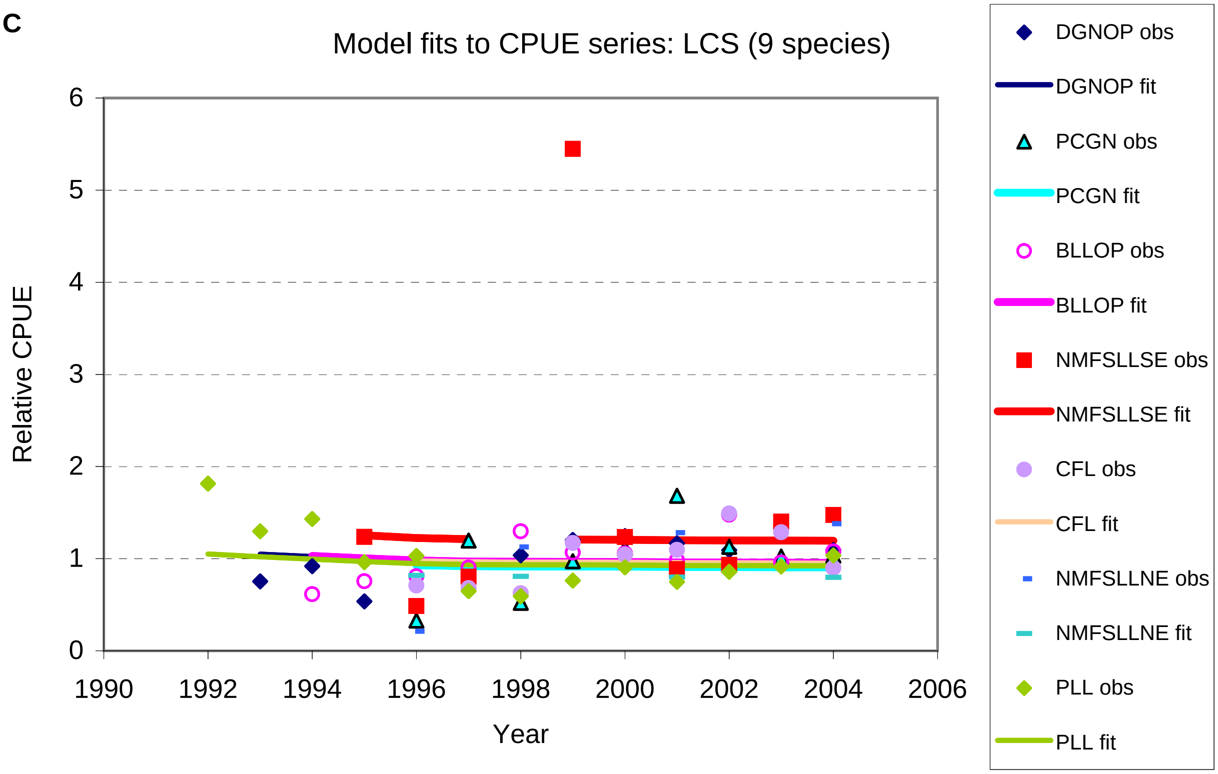


Figure 12. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for LCS without prohibited species, blacktip or sandbar with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Model fits to the individual CPUE series are shown in (C).

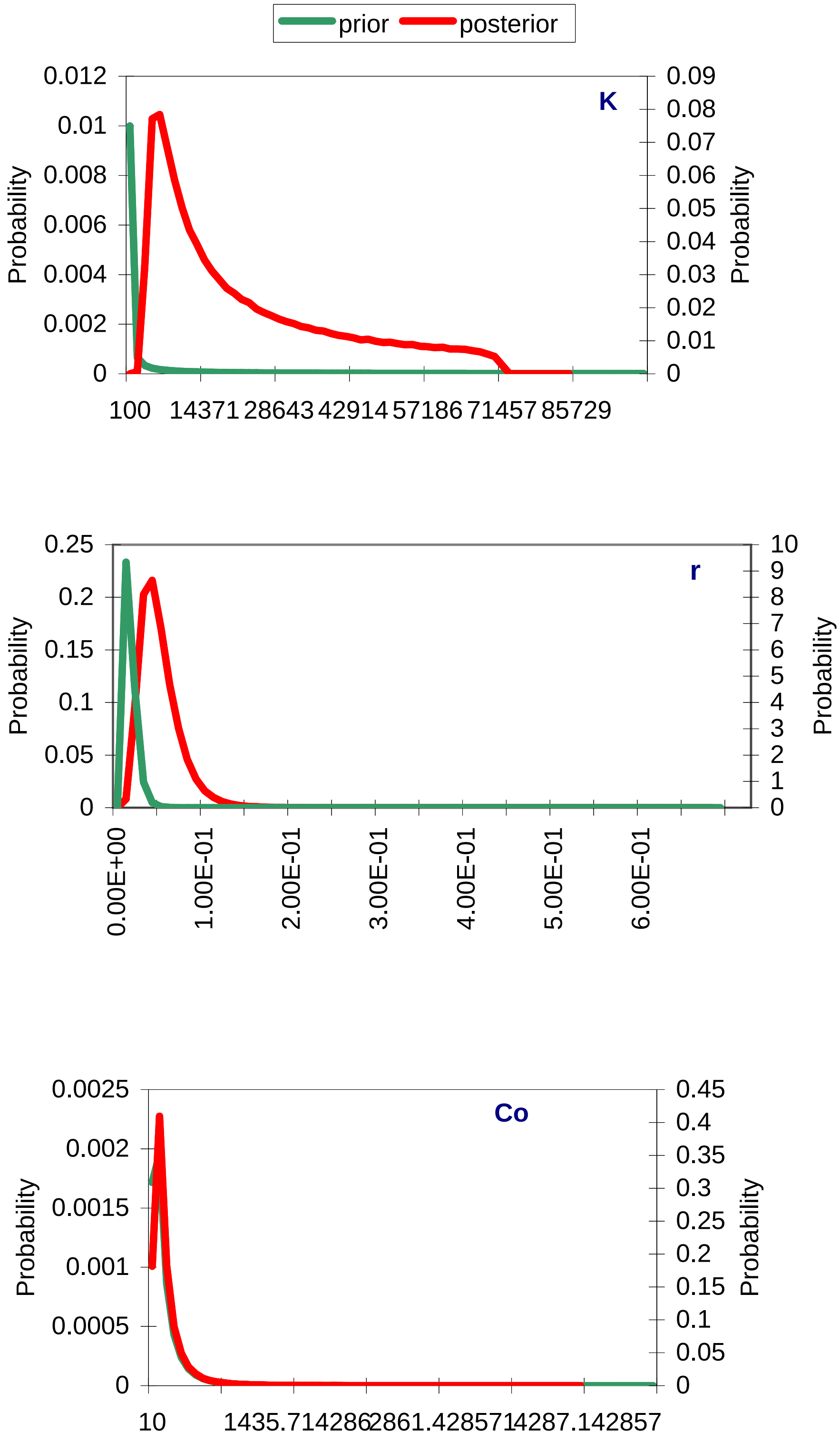
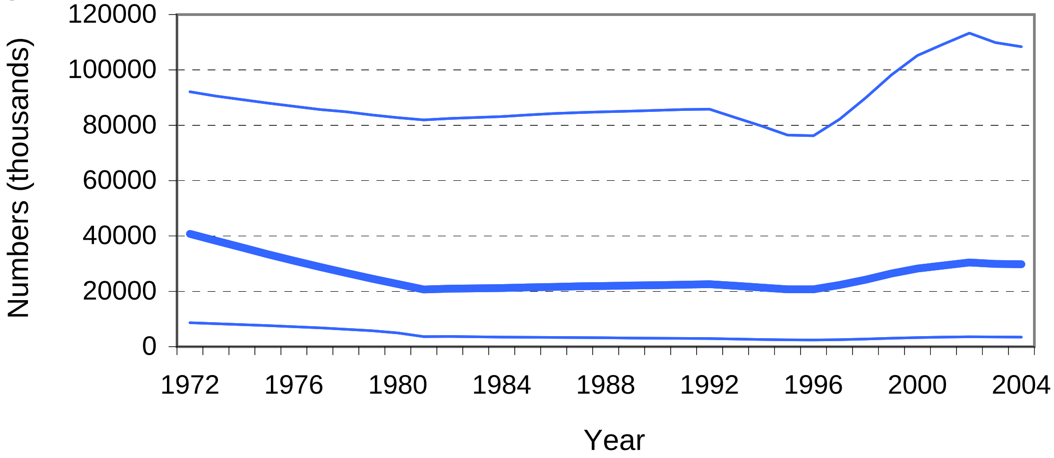
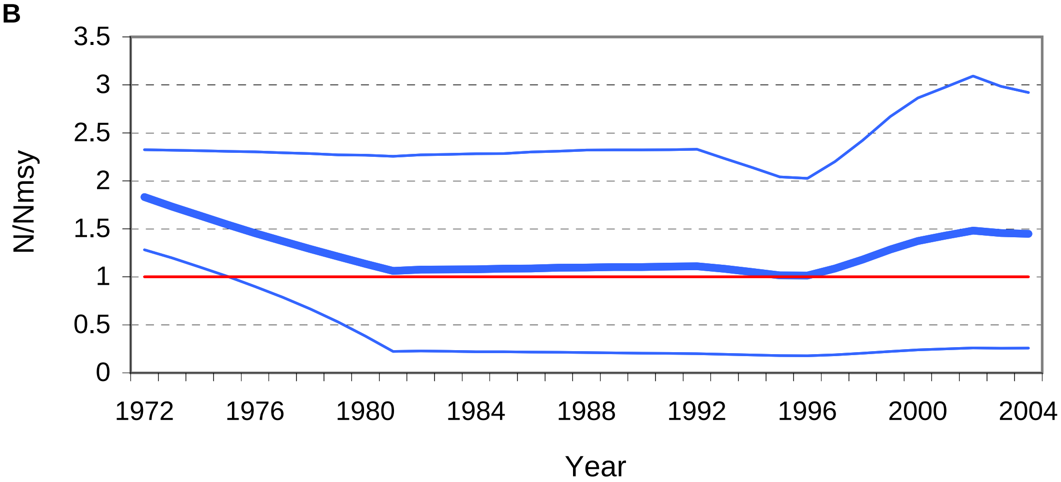


Figure 13. Prior (green) and posterior (red) probability distributions for K, r and Co for LCS without prohibited species, blacktip or sandbar from the BSP model.

A



B



C

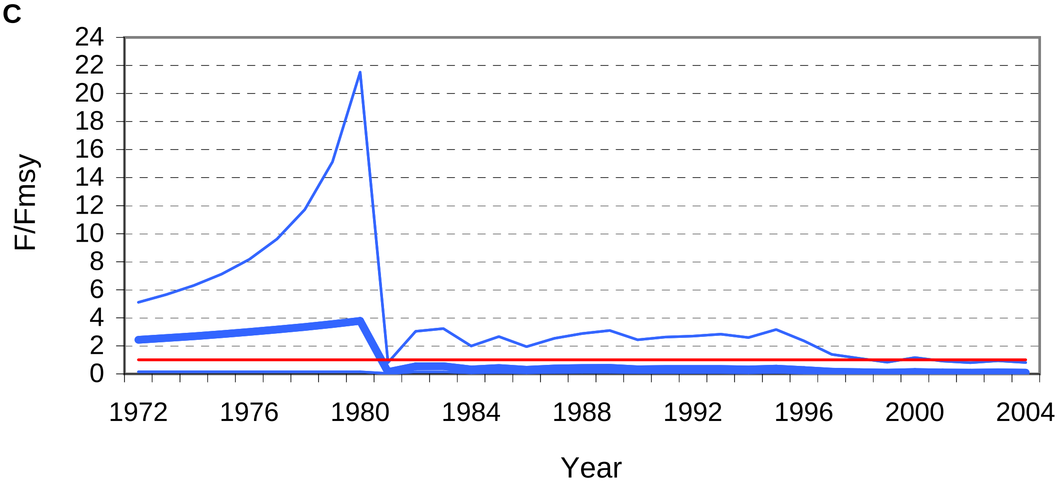


Figure 14. Predicted biomass trend (A), and relative abundance (B) and fishing mortality rate (C) trajectories for LCS without prohibited species, blacktip or sandbar with the WinBUGS model. Values shown are medians with 95% probability intervals; horizontal lines at 1 denote MSY levels.

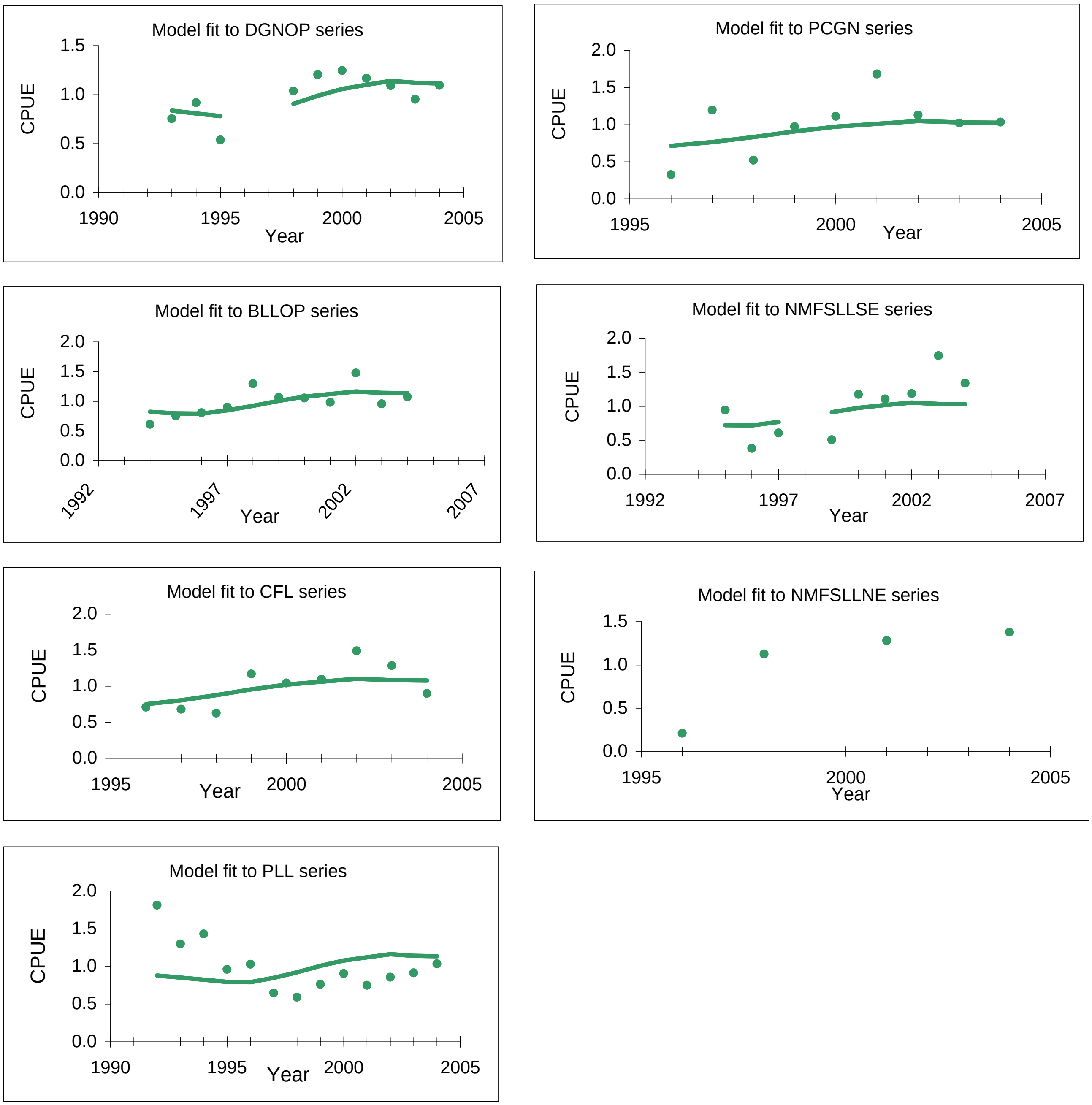


Figure 15. WinBUGS model fits to the individual CPUE series for LCS without prohibited species, blacktip or sandbar.

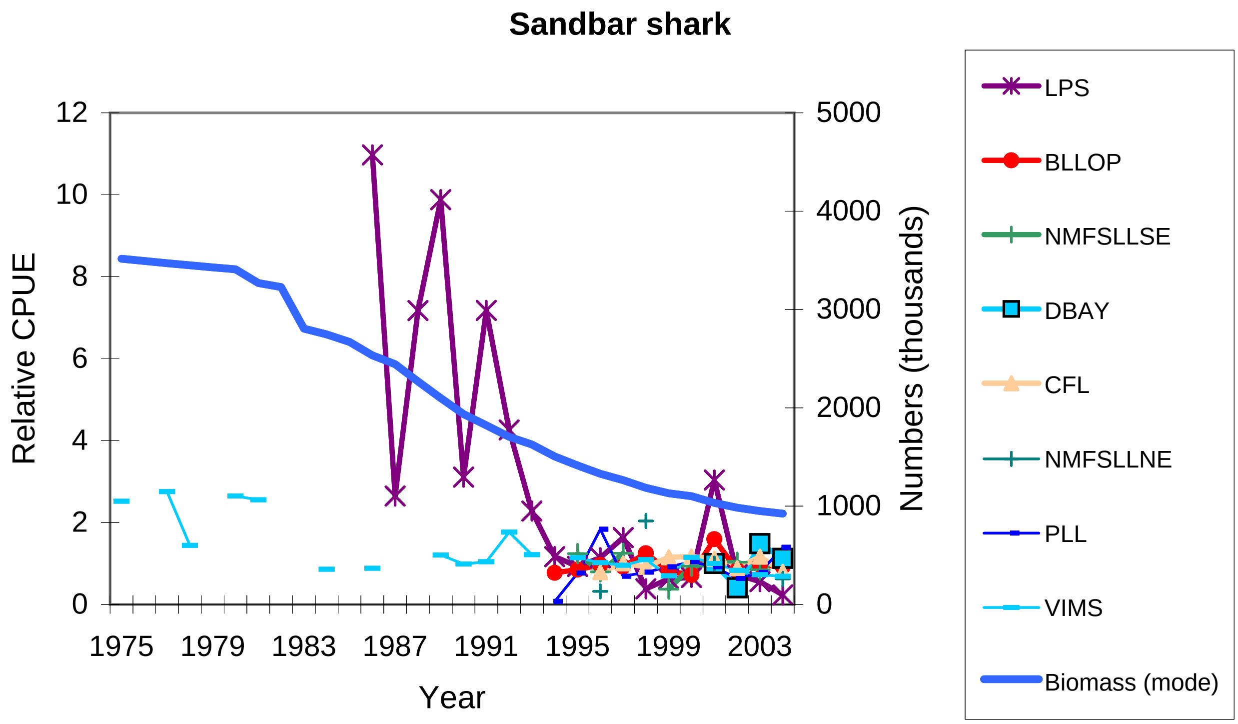
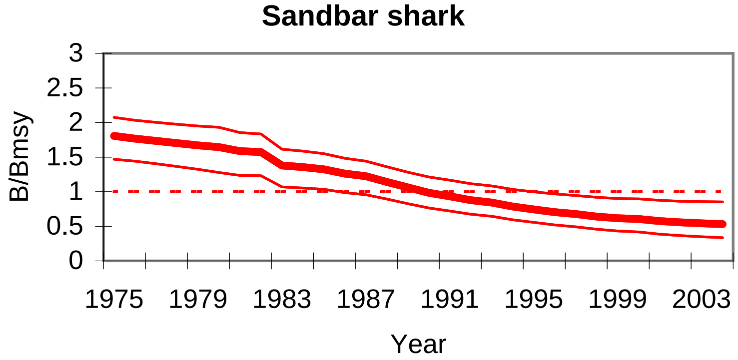
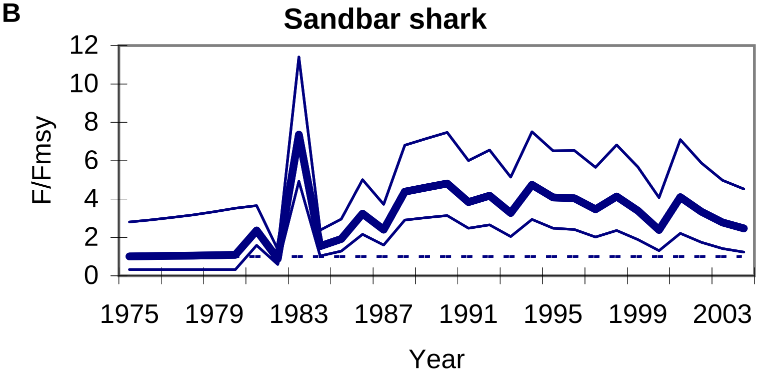


Figure 16. Predicted abundance trend of the BSP model fittted to the catch and CPUE data for sandbar shark CPUE series shown are scaled (divided by the mean of the overlapping years among all series).

A



B



C

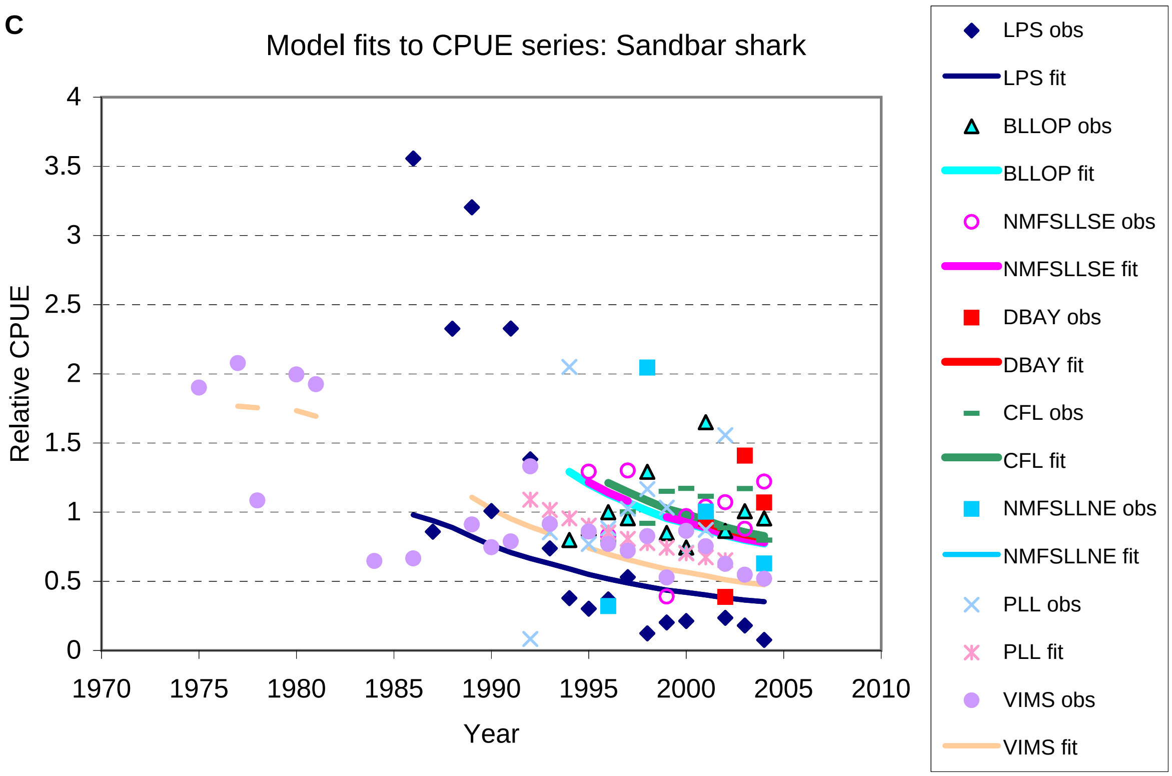


Figure 17. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for sandbar shark with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Model fits to the individual CPUE series are shown in (C).

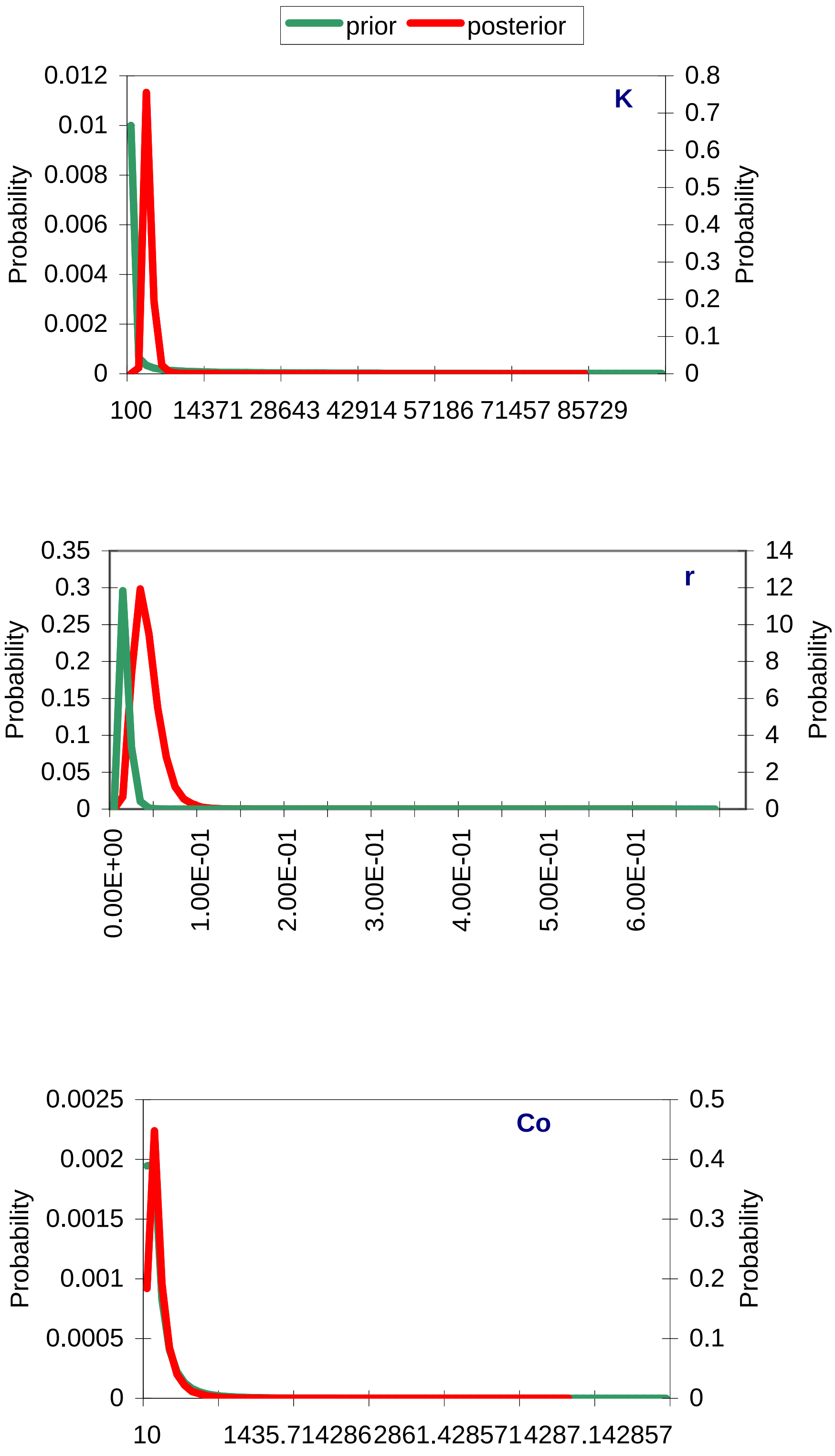


Figure 18. Prior (green) and posterior (red) probability distributions for K, r and Co for sandbar shark from the BSP model.

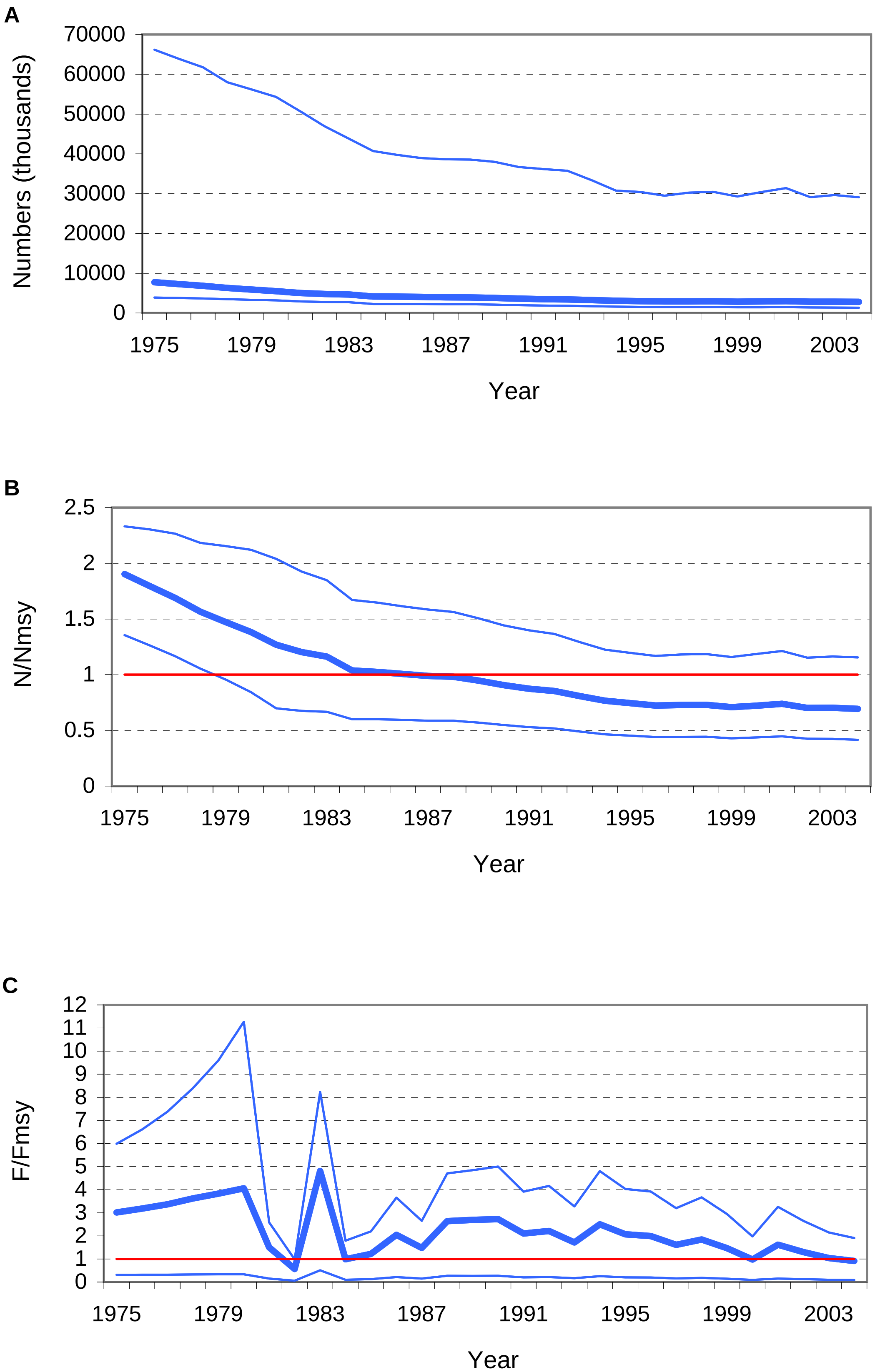


Figure 19. Predicted biomass trend (A), and relative abundance (B) and fishing mortality rate (C) trajectories for sandbar shark with the WinBUGS model. Values shown are medians with 95% probability intervals; horizontal lines at 1 denote MSY levels.

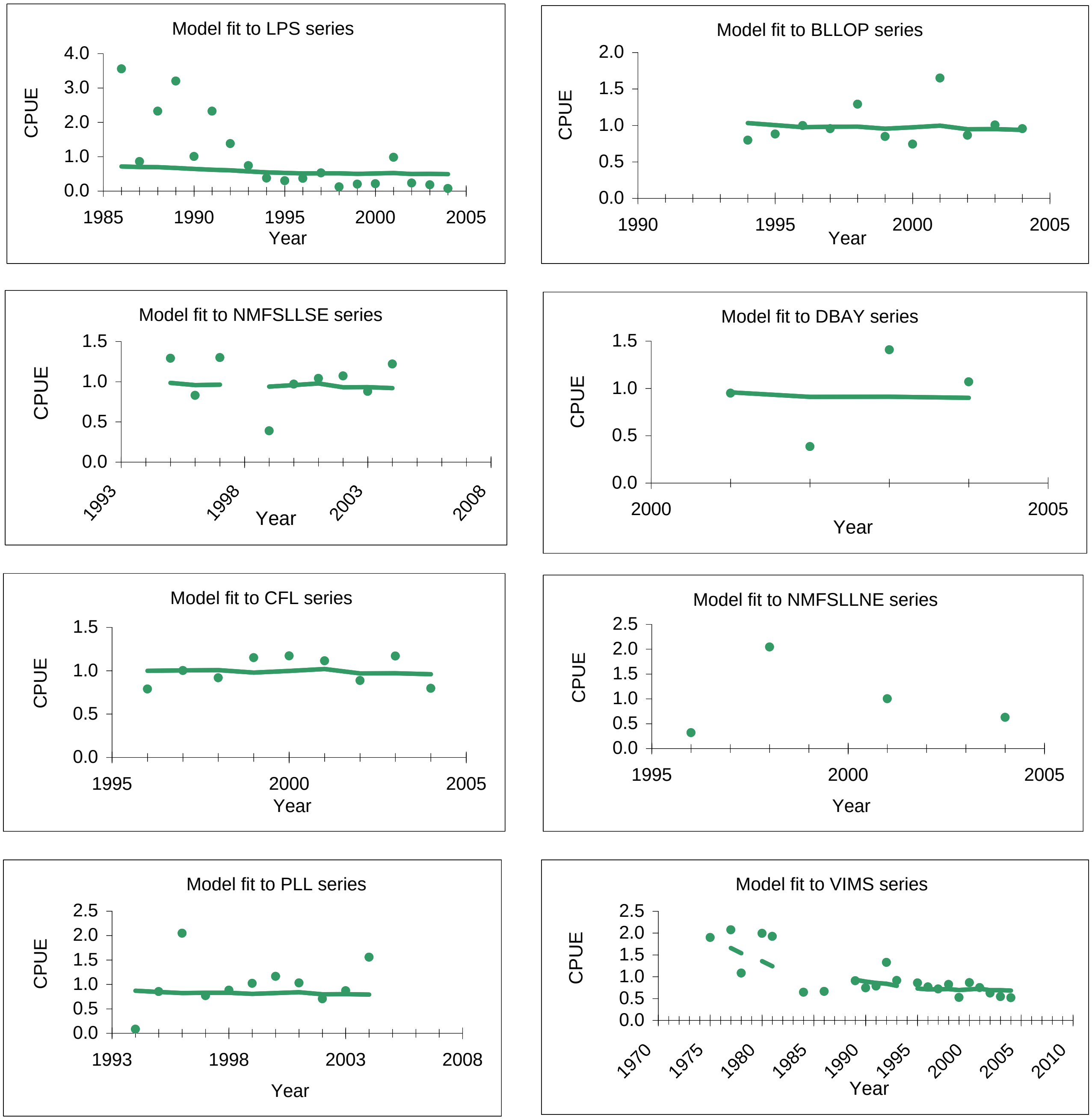


Figure 20. WinBUGS model fits to the individual CPUE series for sandbar shark.

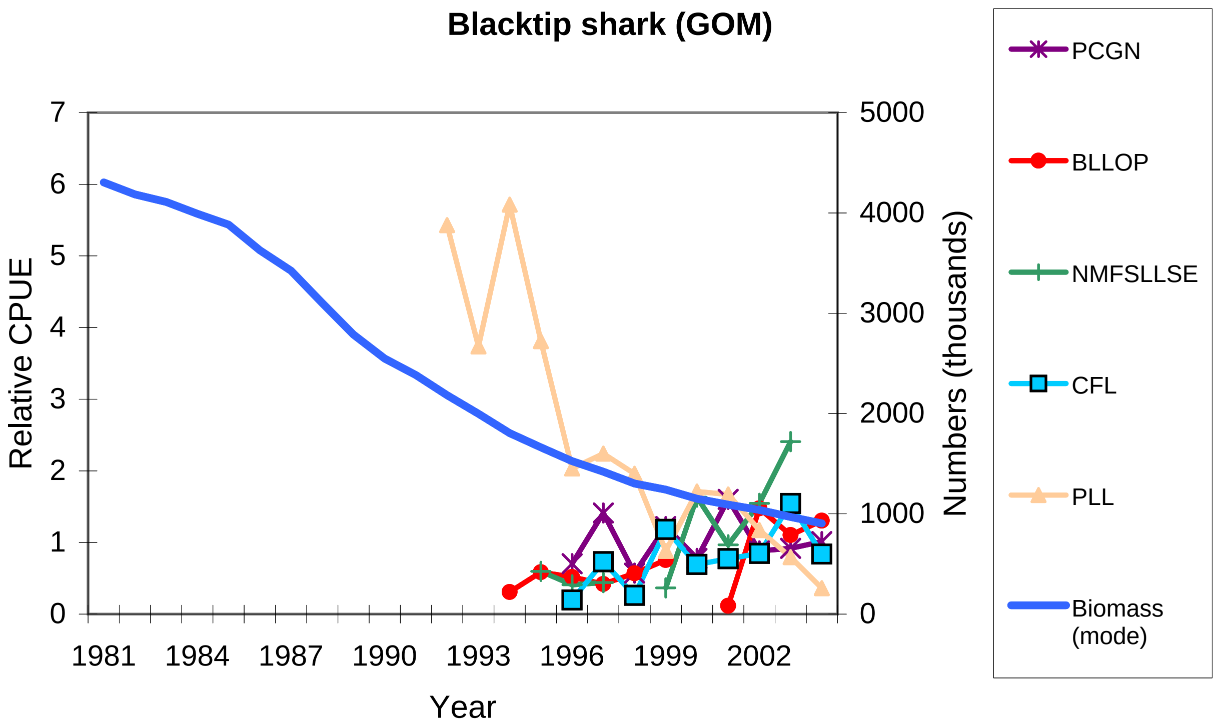


Figure 21. Predicted abundance trend of the BSP model fittted to the catch and CPUE data for blacktip shark (GOM). CPUE series shown are scaled (divided by the mean of the overlapping years among all series).

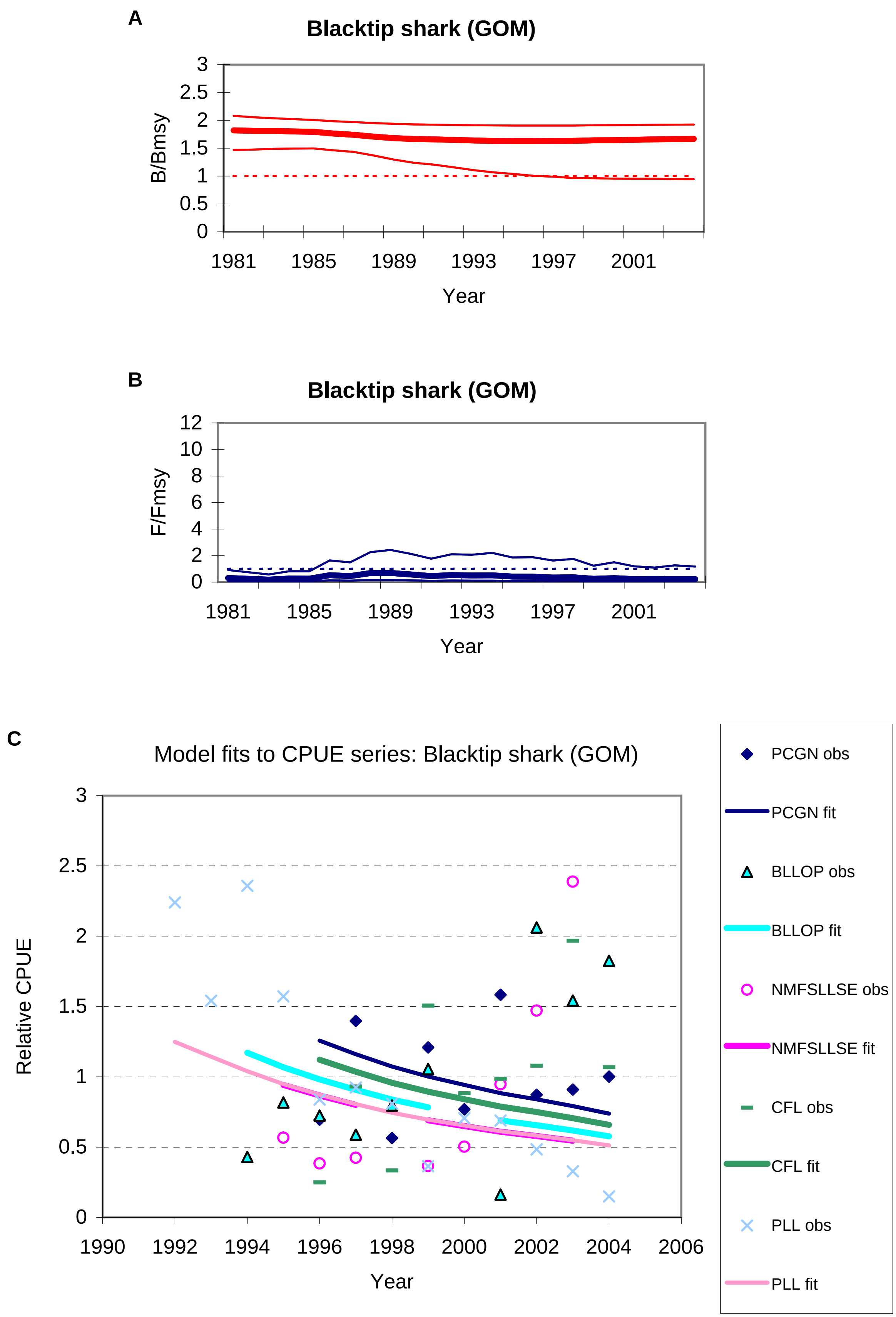


Figure 22. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for blacktip shark (GOM) with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Model fits to the individual CPUE series are shown in (C).

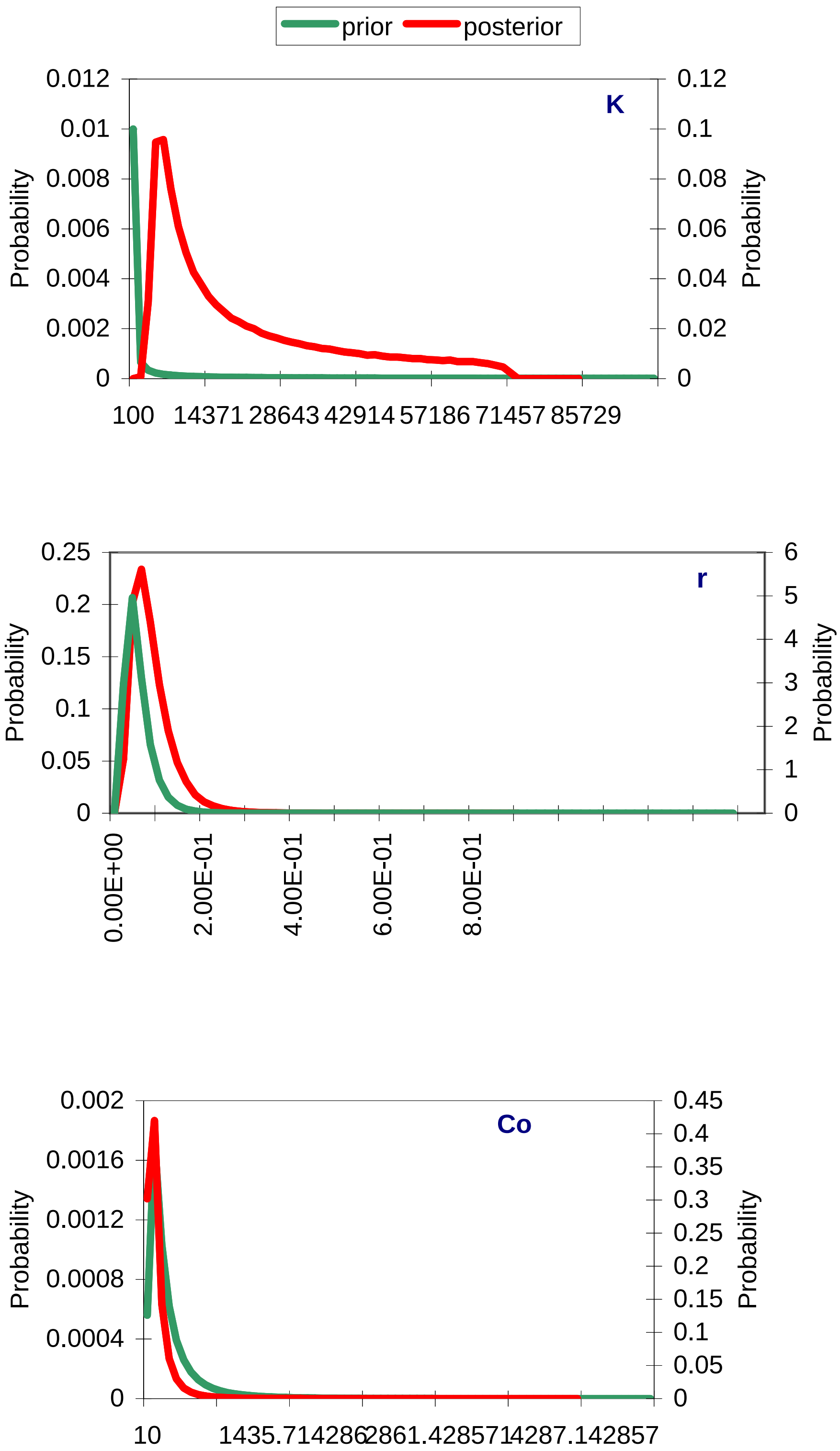
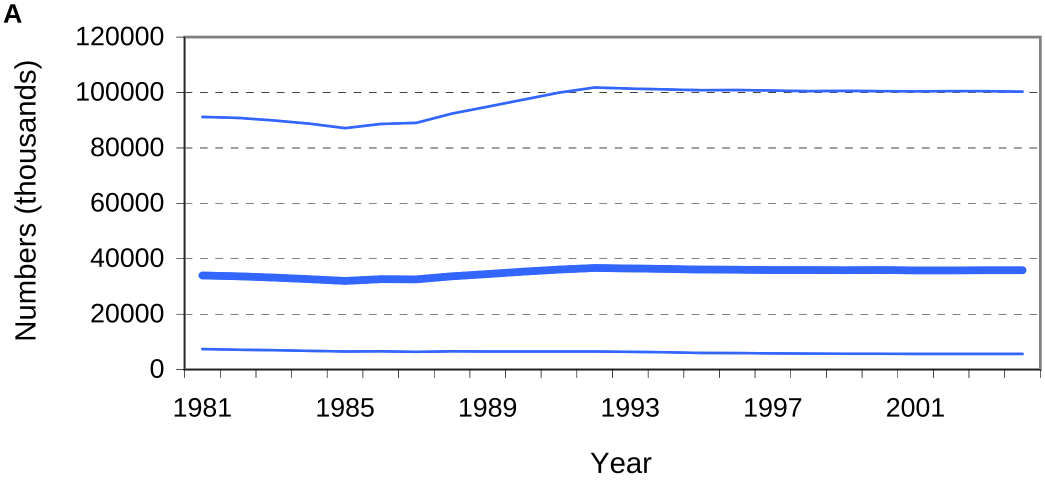
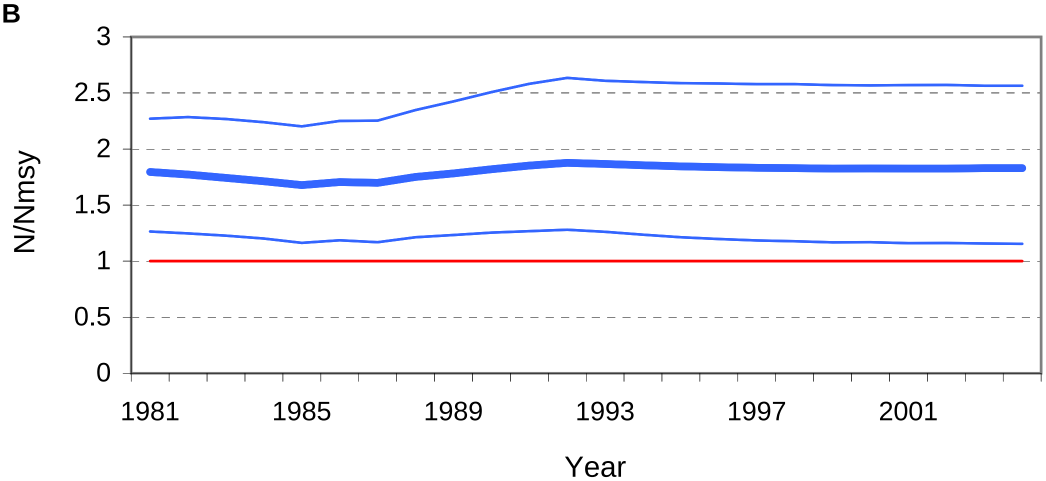


Figure 23. Prior (green) and posterior (red) probability distributions for K, r and Co for blacktip shark (GOM) from the BSP model.

A



B



C

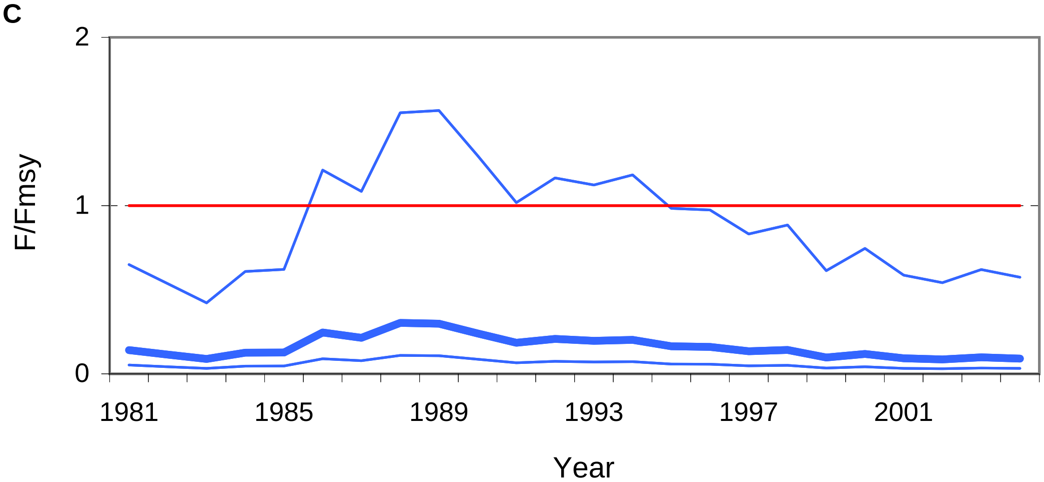


Figure 24. Predicted biomass trend (A), and relative abundance (B) and fishing mortality rate (C) trajectories for blacktip shark (GOM) with the WinBUGS model. Values shown are medians with 95% probability intervals; horizontal lines at 1 denote MSY levels.

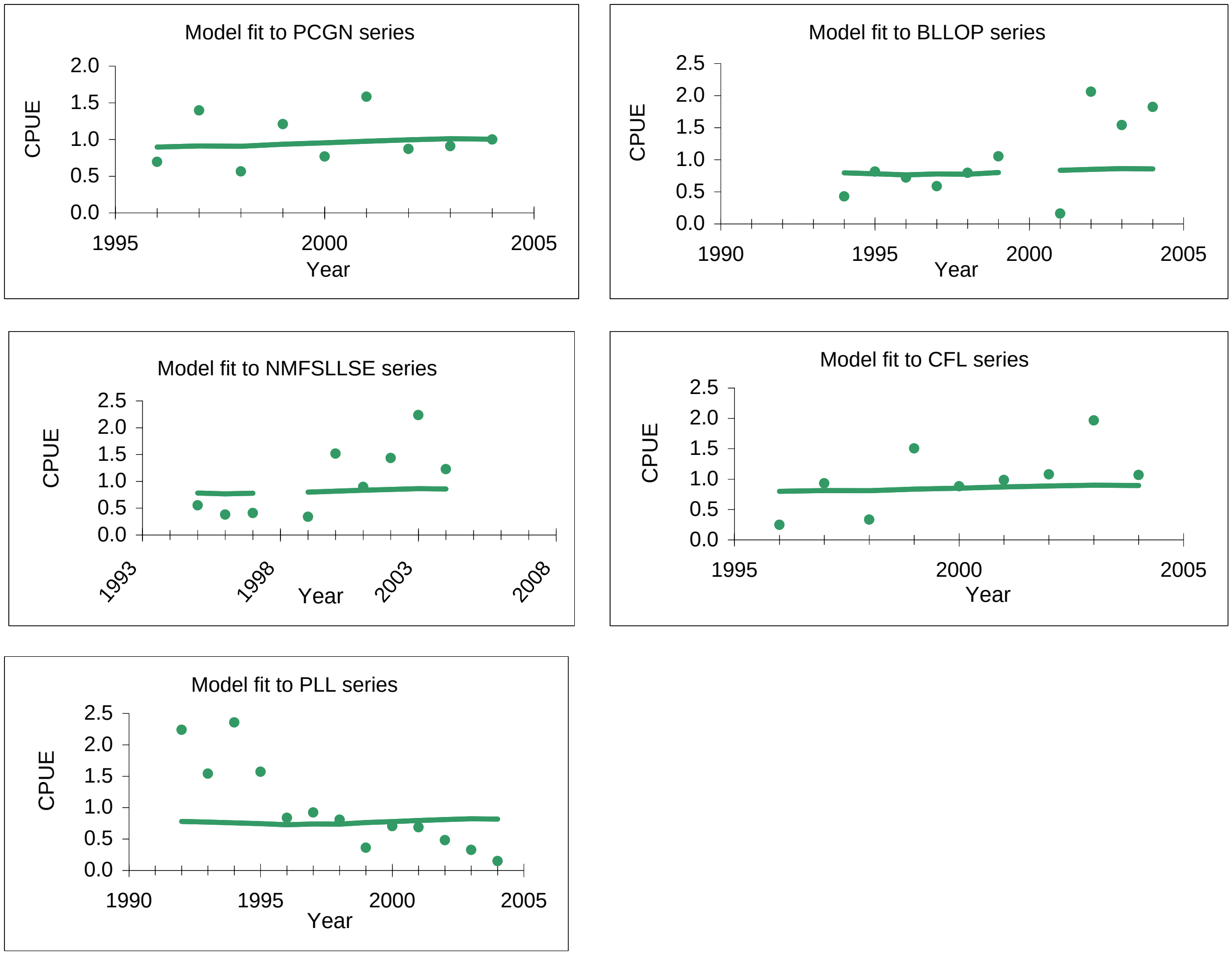


Figure 25. WinBUGS model fits to the individual CPUE series for blacktip shark (GOM).

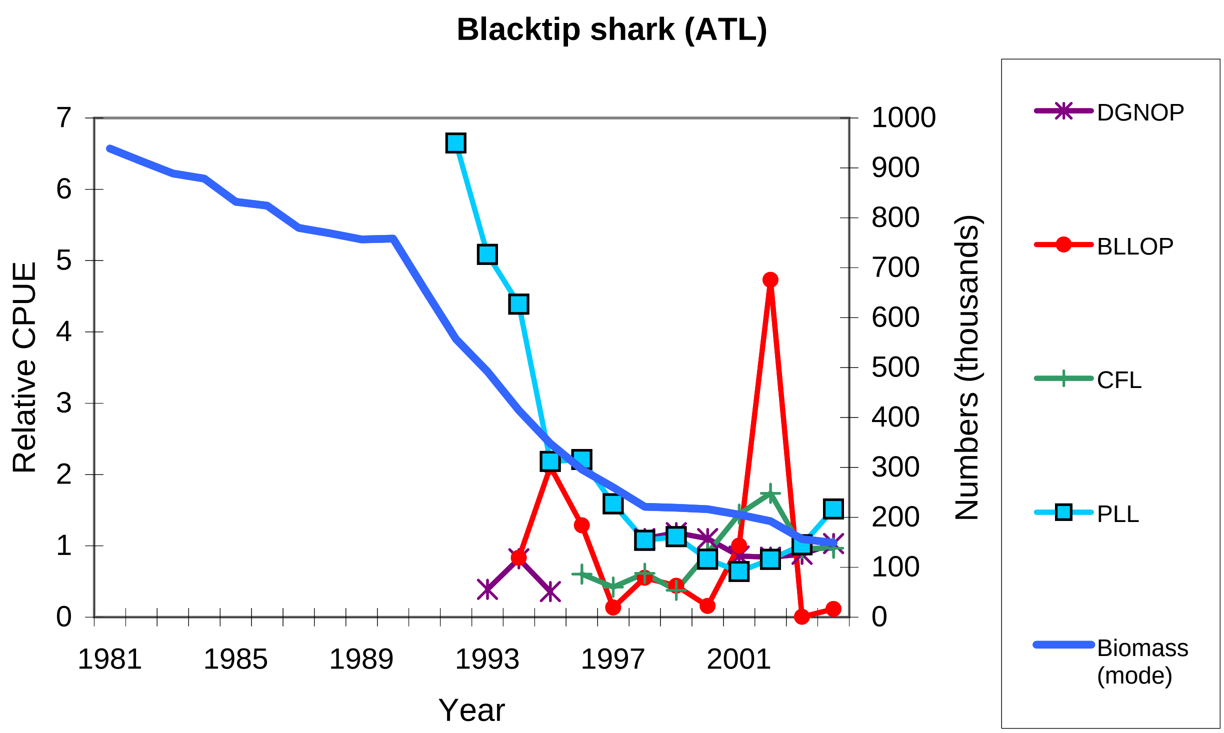
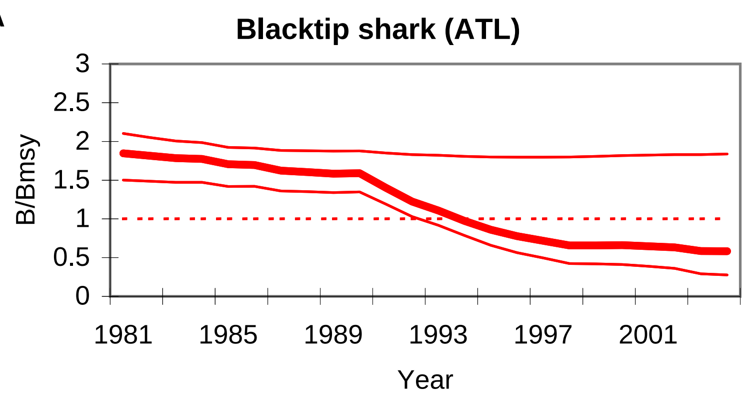
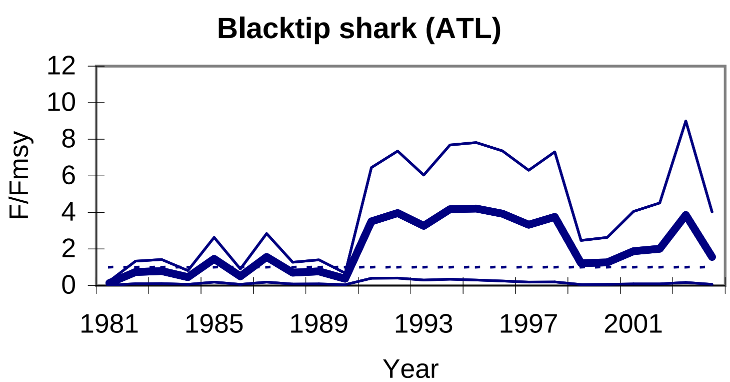


Figure 26. Predicted abundance trend of the BSP model fittted to the catch and CPUE data for blacktip shark (ATL). CPUE series shown are scaled (divided by the mean of the overlapping years among all series).

A



B



C

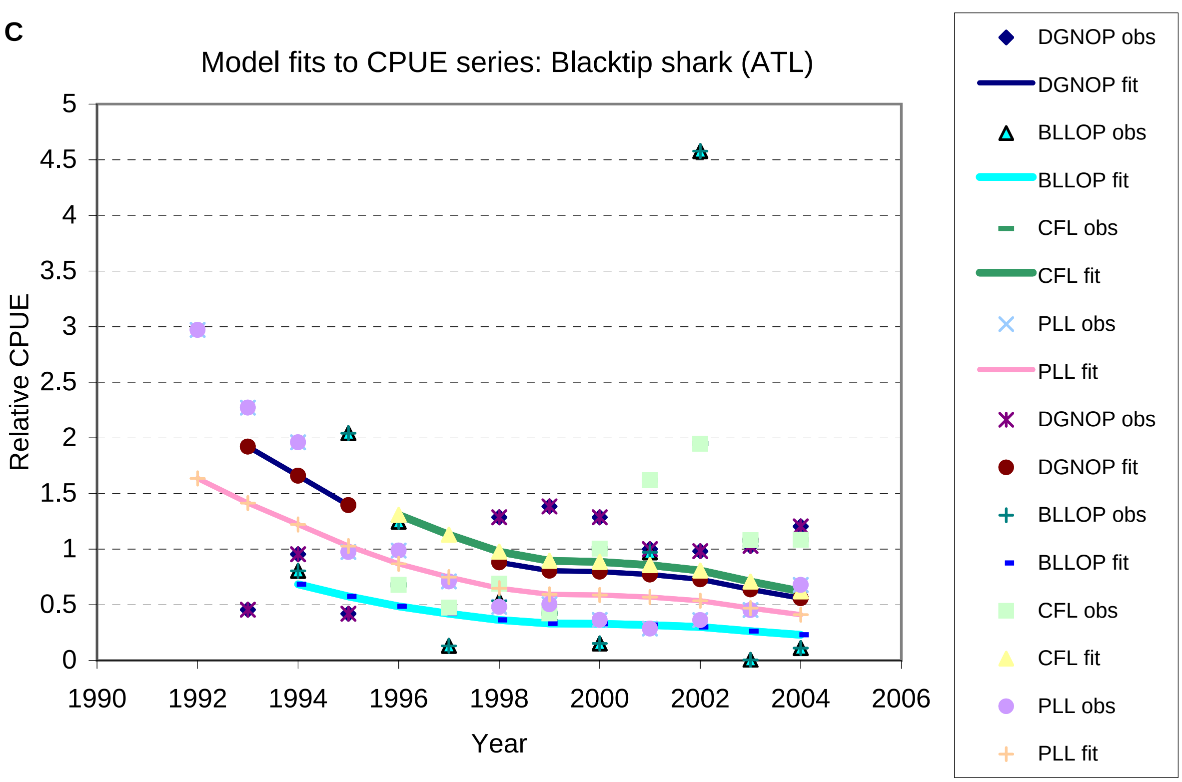


Figure 27. Predicted median relative abundance (A) and fishing mortality rate (B) trajectories for blacktip shark (ATL) with the BSP model. Values shown are medians with 80% probability intervals; horizontal lines at 1 denote MSY levels. Model fits to the individual CPUE series are shown in (C).

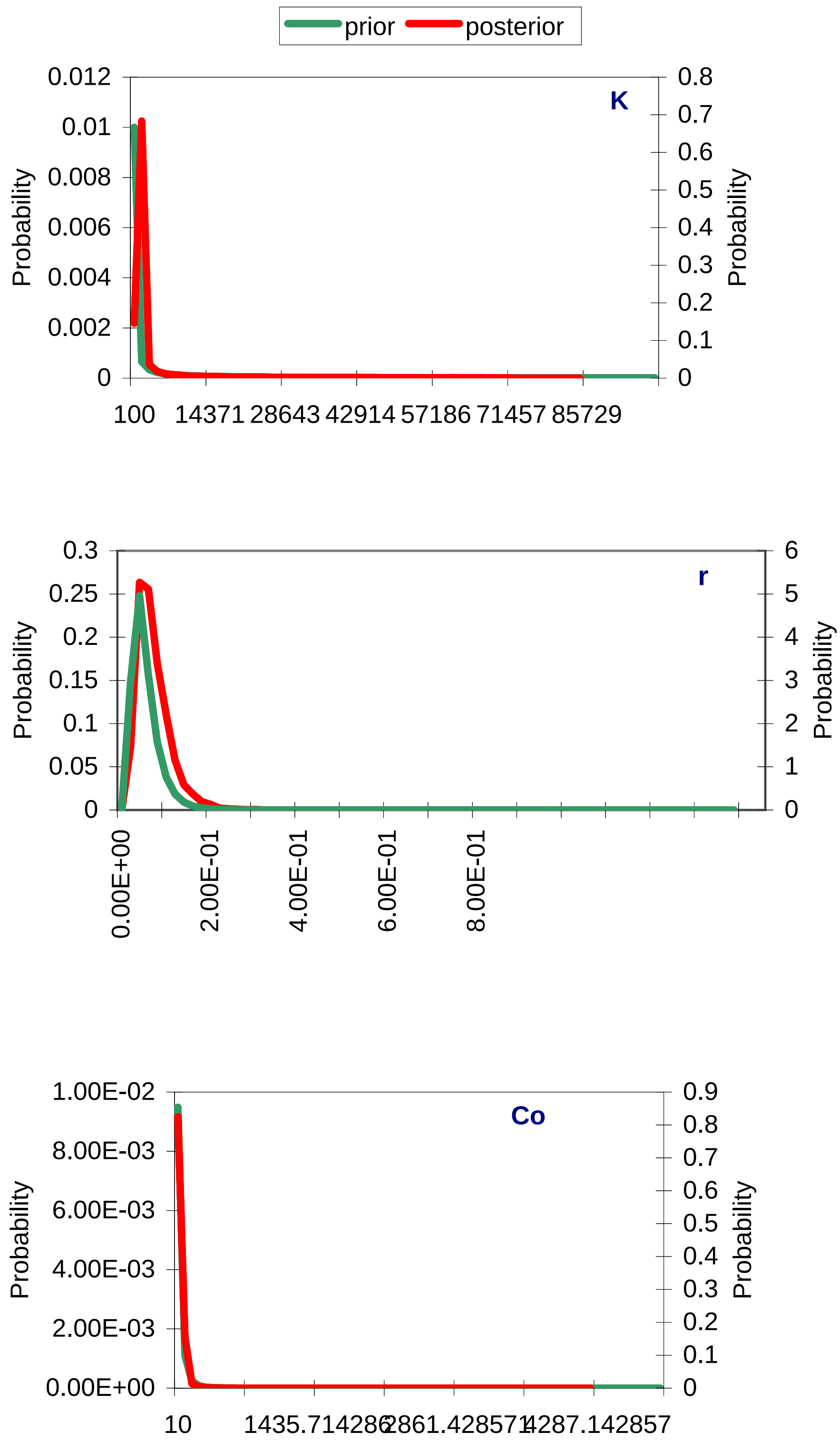


Figure 28. Prior (green) and posterior (red) probability distributions for K, r and Co for blacktip shark (ATL) from the BSP model.

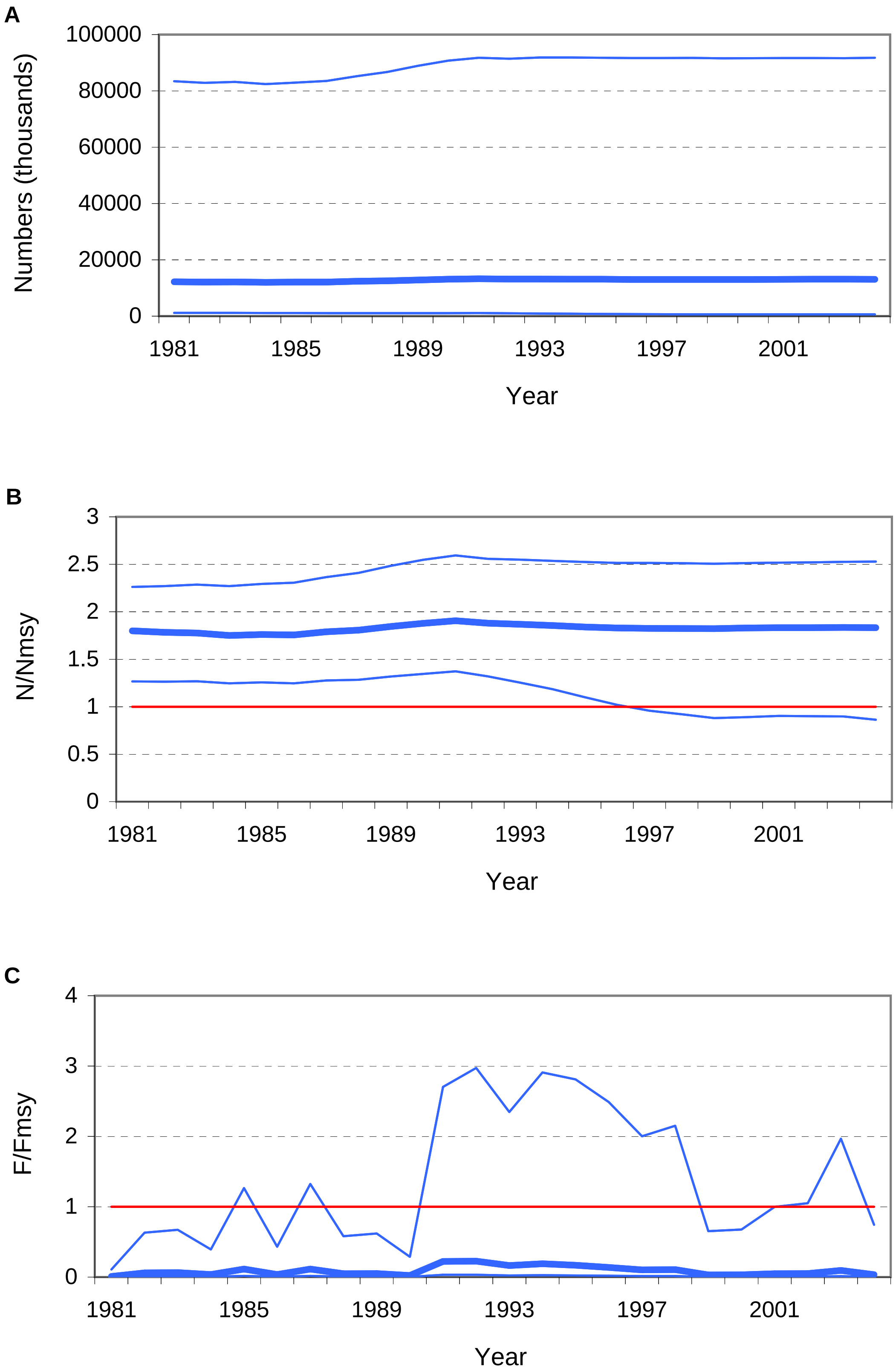


Figure 29. Predicted biomass trend (A), and relative abundance (B) and fishing mortality rate (C) trajectories for blacktip shark (ATL) with the WinBUGS model. Values shown are medians with 95% probability intervals; horizontal lines at 1 denote MSY levels.

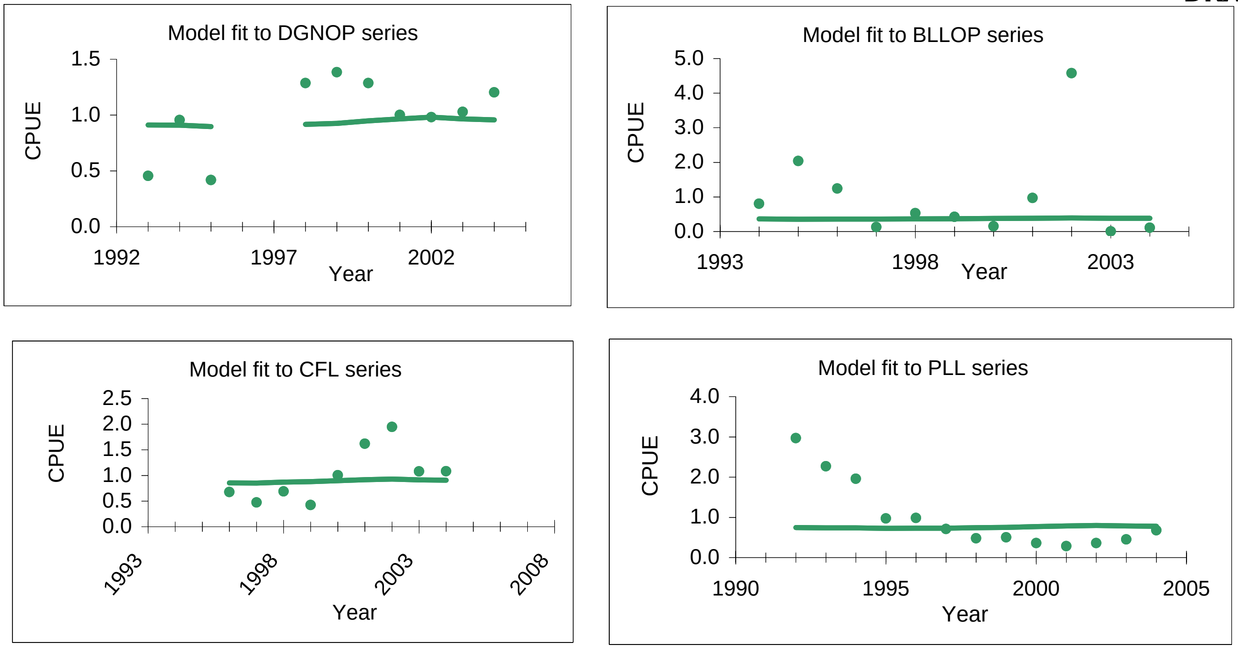


Figure 30. WinBUGS model fits to the individual CPUE series for blacktip shark (ATL).