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

Enric Cortés

March, 2002

Sustainable Fisheries Division Contribution SFD-01/02-152

National Marine Fisheries Service
Southeast Fisheries Science Center
Panama City Laboratory
3500 Delwood Beach Road
Panama City, FL 32408

## SUMMARY

Several species of small coastal sharks are caught in directed fisheries and as bycatch in waters off the eastern coast of the U.S.A. This management group presently includes the Atlantic sharpnose (*Rhizoprionodon terraenovae*), bonnethead (*Sphyrna tiburo*), blacknose (*Carcharhinus acronotus*), and finetooth (*Carcharhinus isodon*) sharks. A stock assessment of the small coastal shark complex was conducted over a decade ago and the ensuing management plan classified this group as being fully utilized. A substantial amount of information has become available since then, including biological data, improved fisheries statistics, and bycatch estimates from the shrimp trawl fishery. A number of fishery-independent and fishery-dependent catch rate series have also become available or their duration been extended. In all, there is now sufficient information to conduct stock assessments of the small coastal shark complex and the individual species. The objective of the current study is thus to assess the status of small coastal shark stocks in the southeastern U.S. region.

Commercial and recreational landings represent only a small fraction of all catches, because small coastal sharks are also caught as bycatch and discarded in a variety of fisheries, in particular the shrimp trawl fishery. Commercial landings in numbers exceed recreational harvest in all years since the quota monitoring system was implemented, except for 1995. The vast majority of small coastal sharks caught in commercial fisheries are landed in the southeastern region. By species, except for 1995 and 2000, Atlantic sharpnose sharks accounted for over one third of all small coastal shark (SCS) commercial landings from 1996-1999, whereas finetooth sharks accounted for over one third of the landings in 1998-2000. During 1995-2000, the vast majority of small coastal sharks were caught in the South Atlantic region, mostly with gillnets. Recreational fishing estimates obtained from three data collection programs (MRFSS, Headboat Survey, and TXPWD) peaked at about 187,000 fish in 2000. The recreational catches were dominated by the Atlantic sharpnose shark in all years (about 3/4 of the total catches in 1995 and 1998, and above 60% in 1996, 1997, 1999, and 2000), and bonnetheads were consistently the second-most important species caught recreationally from 1995-2000.

Average size information for the SCS complex and the four main species of SCS was available from several commercial and recreational sources and was used to transform numbers of fish into weights and vice versa. Estimates of the bycatch of Atlantic sharpnose and bonnethead in the U.S. shrimp trawl fishery operating in the U.S. South Atlantic and Gulf of Mexico regions indicate that they exceed in importance the landings for these shark species.

A total of 41 catch rate series for small coastal sharks were examined: 9 series were available for the small coastal shark complex, 13 for Atlantic sharpnose shark, 5 for bonnethead, 8 for blacknose shark, 5 for finetooth shark, and 1 for Atlantic angel shark. The available CPUE series were of different magnitude and quality; all the series that were received without prior analysis were subjected to the same Generalized Linear Model (GLM) standardization methodology to adjust for factors that affect relative abundance. The approach used to estimate relative abundance indices was a Generalized Linear Mixed Model that treats separately the proportion of sets with positive catches (i.e., where at least one shark was caught) assuming a binomial error distribution with a logit link function, and the catch rates of sets with positive catches assuming a Poisson error distribution with a log link function. Statistical analysis of

trends in CPUE series revealed rather flat trends as evidenced by a general lack of steepness of the slopes, suggesting that stocks have remained fairly stable during the exploitation phase.

Vital rates of the four species of small coastal sharks were used to predict the productivity of the stocks. Estimates of productivity were then used in helping to define prior probability distributions in the Bayesian stock assessment section. To avoid the occurrence of negative values of the intrinsic rate of population increase (r), which can be obtained when using life tables, only a modified demographic technique that ensures positive values of r was used. This method assumes that density dependence operates as increased survival during the pre-recruit stages and, like more conventional demographic approaches, models only the female portion of the population.

Several stock assessment models were used to evaluate the status of small coastal sharks using Bayesian statistical techniques. First, a nonequilibrium Schaefer biomass dynamic model was used to describe the population dynamics of exploited small coastal shark stocks using the SIR algorithm and two weighting schemes: 1) an equal weighting scenario in which a single value of variance for all series was estimated through a uniform prior on the log scale, and 2) a scenario in which the weight was the Maximum Likelihood Estimate of the variance for each series. Second, a nonequilibrium Schaefer surplus production model (SPM) was also used to describe the population dynamics of exploited small coastal shark stocks using a Markov Chain Monte Carlo (MCMC) method for numerical integration. In this approach, a state-space model accounts for both process error and observation error in a unified analytical framework that uses Gibbs sampling to sample from the joint posterior distribution. Finally, a lagged recruitment, survival, and growth (LRSG) state-space model was also used to model the dynamics of small coastal shark stocks. This model takes into account the lag between birth and subsequent recruitment to the adult stock, and thus some of the age structure of the stock.

Results of the base-case and extensive alternative scenarios using both surplus production models and the LRSG model indicate that the current level of removals is sustainable for the small coastal shark aggregate and the individual species. Relative stock biomass and fishing mortality trajectories obtained with the Bayesian state-space SPM for the small coastal aggregate and Atlantic sharpnose followed similar trends, since the catches were dominated by this species. The model predicted that the stock biomass in any given year from 1972-2000 exceeded the biomass producing MSY. Relative fishing mortality ($F/F_{MSY}$) was generally below 1, but there were several years for the small coastal aggregate and two years for the Atlantic sharpnose when the fishing mortality on the stock was estimated to exceed that which would produce MSY. For bonnethead, all values of biomass were well above that producing MSY, and only in 1995 was fishing mortality estimated to exceed that producing MSY. For blacknose, all values of biomass were above that producing MSY and all values of F were below that producing MSY. For finetooth, only the final five values of F in the series were estimated by the model to be above the level of F producing MSY.

Relative biomass and relative harvest rate trajectories estimated through the Bayesian state-space LRSG model showed similar patterns to those estimated with the Bayesian state-space SPM, but on different scales. Predictions of both relative biomass and relative harvest rate ($H/H_{MSY}$) from the Bayesian LRSG model tended to be higher for the small coastal aggregate.

For Atlantic sharpnose and bonnethead, relative biomass was higher, and relative harvest rates, lower. For blacknose, relative biomass was higher, but relative harvest rate was very similar, with the 97.5th percentile being higher in the Bayesian LRSG model. For finetooth, relative biomass was higher, and relative harvest rate tended to be lower in the Bayesian LRSG model.

While results for blacknose and finetooth sharks are more uncertain due to shorter catch and CPUE series, lack of bycatch estimates, and no catches reported in some years, the main conclusion from the present assessment work is that stocks of small coastal sharks in waters off the eastern coast of the U.S. are in no immediate danger of collapse. This conclusion is supported by the results of the alternative models used, which incorporated separate population dynamics models of the stocks, different assumptions about the error structure of the data, several weighting schemes for the CPUE series, and two separate algorithms for numerical integration. Sensitivity analyses investigating alternative priors for several parameters and different catch and CPUE series, in addition to the analysis of trends in CPUE series, further supported the conclusion that stocks of small coastal sharks can sustain the present removal levels.

## BACKGROUND

The first federal fisheries management plan (FMP) for sharks was implemented in 1993 (NMFS 1993). In this FMP for Sharks of the Atlantic Ocean, three management groups were identified: large coastal, small coastal, and pelagic. The small coastal complex included seven species: Atlantic angel (*Squatina dumerili*), Atlantic sharpnose (*Rhizoprionodon terraenovae*), blacknose (*Carcharhinus acronotus*), bonnethead (*Sphyrna tiburo*), Caribbean sharpnose (*Rhizoprionodon porosus*), finetooth (*Carcharhinus isodon*), and smalltail (*Carcharhinus porosus*). The 1993 FMP classified small coastal sharks as being fully utilized. The basis for this conclusion was a stock assessment based on a surplus production model of the whole small coastal shark aggregate that utilized the limited fisheries data available at the time, which included the period 1986-1989 (Parrack 1990). It was estimated that the maximum sustainable yield (MSY) for small coastal sharks was 2,590 mt dressed weight (the 1989 estimate of production), and the total quota was set at that level.

As a result of indications that the abundance of large coastal sharks had declined, in 1997 the commercial quota for the large coastal complex was reduced from 2,570 to 1,285 mt. A commercial quota for small coastal sharks was also established at 1,760 mt and the recreational bag limit for all Atlantic sharks was reduced to 2 sharks per vessel per trip (from 5), with an additional allowance of 2 Atlantic sharpnose sharks per person per trip. The reduction in the large coastal shark group commercial quota brought about a change in commercial fishers' behavior, who began to land increasing numbers of small coastal sharks to offset the lower quotas for large coastal sharks.

Based in part on the results of the 1998 Shark Evaluation Workshop (NMFS 1998), in 1999 the National Marine Fisheries Service (NMFS) introduced new management measures intended to further restrict commercial quotas and recreational bag limits on sharks. These measures were presented in the new FMP for Atlantic Tunas, Swordfish, and Sharks (NMFS

1999) and for small coastal sharks they included: 1) a reduction in the recreational bag limit to 1 Atlantic shark per vessel per trip, with a minimum size of 137 cm fork length for all sharks, and an additional 1 Atlantic sharpnose shark per person per trip; 2) a reduction in the annual commercial quota for small coastal sharks to 359 mt dw; and 3) making the Atlantic angel, Caribbean sharpnose, and smalltail sharks prohibited species. The new, precautionary commercial quota was set as 10% over the 1997 catch as recognition that increasing pressure was being placed on stocks of small coastal sharks. This quota, however, has not been implemented pending a litigation settlement agreement.

A substantial amount of information has become available since the first stock assessment of small coastal sharks was conducted in 1990 (Parrack 1990). During the past decade biological studies on age and growth, reproduction, and population dynamics of the four main species (Atlantic sharpnose, bonnethead, blacknose and finetooth) of small coastal sharks have been conducted. Commercial landings statistics and more complete and extended estimates of recreational catches have become available, as well as extended estimates of bycatch of some of these species in shrimp trawl fisheries. An observer program of the bottom longline fishery targeting large coastal sharks now provides useful information on species and size composition, and disposition of catches of small coastal sharks. Average sizes are available from three recreational surveys that include information on small coastal sharks. A number of fishery-independent and fishery-dependent catch rate series have also become available or their duration been extended. In all, there is now sufficient information to conduct stock assessments of the small coastal shark complex and of some individual species. The objective of the current study is thus to assess the status of small coastal shark stocks in the southeastern U.S. region.

## CATCHES

Recent trends in commercial and recreational landings of this grouping and of the four commonly caught species comprising it are presented (updated from Cortés 2000a). These landings are estimated to represent only a small fraction of all catches, because small coastal sharks (SCS) are also caught as bycatch and discarded in a variety of fisheries, in particular the shrimp trawl fishery. Data from the directed shark fishery observer program targeting large coastal sharks also indicate that sharks in the SCS complex are generally not landed, but used for bait.

### Commercial Harvest Estimates

Commercial landings estimates of small coastal sharks in U.S. waters were obtained from the Southeast Regional general canvass program and the Southeast Fisheries Science Center (SEFSC) quota monitoring program, which is based on reports from dealers holding permits to land sharks. The quota monitoring data typically provide a more diverse species listing than the general canvass data. Prior to 1995, commercial landings of small coastal sharks were only reported in the general canvass program, and were insignificant (<1 mt for 1991 and 1993, about 7 mt in 1994). Commercial landings estimates for 1995-2000 were obtained by taking the larger reported landing estimate of a given species in the two data sets.

Commercial landings in numbers exceed recreational harvest in all years since the quota monitoring system was implemented, except for 1995 and 2000 (Table 1). Commercial landings peaked at 330 mt dw in 1999 or about 223,000 fish (calculated using average weights predicted from lengths measured in the directed shark fishery observer program).

Four species of small coastal sharks (Atlantic sharpnose, bonnethead, blacknose, and finetooth) are regularly landed in commercial fisheries, the vast majority in the southeastern region. By species, bonnetheads made up over 50% of all SCS commercial landings in 1995, but were the least important species represented in commercial landings for the remaining years, 1996-2000 (Table 2). Except for 1995 and 2000, Atlantic sharpnose sharks accounted for over one third of all SCS commercial landings from 1996-1999, whereas finetooth sharks accounted for over one third of the landings in 1998-2000.

During 1995-2000, the vast majority of small coastal sharks were caught in the South Atlantic region (57% and over; Figure 1). In all those years, gillnets were the dominant type of gear catching small coastal sharks in the South Atlantic region (Figure 1). In the Gulf of Mexico region, almost all small coastal sharks landed were caught in longlines in 1995-1997, and 2000, whereas the proportion of sharks caught in gillnets increased in 1998 and 1999 (to over 1/3 of the total). Most small coastal sharks were landed in Florida's east coast in 1998, 1999, and 2000 (93%, 80%, and 68%, respectively), the majority of which were caught with drift gillnet gear. Interestingly, the state of New York accounted for 10% and 21% of total SCS landings in 1999 and 2000, respectively.

Almost all Atlantic sharpnose sharks were caught in the South Atlantic region from 1995-2000 (97% and over). Except for 1995, when about 2/3 of the landings corresponded to longline gear, gillnets were the dominant type of gear in the South Atlantic region all other years from 1996 to 2000 (Figure 2). In the Gulf of Mexico region, almost all Atlantic sharpnose sharks landed were caught in longlines, except for about 1/3 of the total being caught in gillnets in 1998.

Finetooth sharks were also almost exclusively caught in the South Atlantic region (Figure 3). Of those, over 80% in any single year were caught in gillnets, except for 1995 when about 90% of the catch corresponded to longlines. For the blacknose shark, the South Atlantic region was also the main region of landing, but to a lesser degree than for the Atlantic sharpnose and finetooth sharks, especially in 1995 when 65% of the landings corresponded to the Gulf of Mexico region (Figure 4). In that year, all blacknose sharks landed in the South Atlantic region were also caught in longlines, whereas from 1996-2000 at least 2/3 of all landings corresponded to gillnet gear. Bonnetheads were also predominantly landed in the South Atlantic region each year (Figure 5). In that region, gillnets were the main gear in all years, except in 1996 when both gillnets and longlines accounted for about 1/2 of all landings each.

**Recreational Harvest Estimates**

Recreational fishing estimates were obtained from three data collection programs extensively described elsewhere (see Cortés 2000a and references therein): the Marine Recreational Fishery

Statistics Survey (MRFSS), the NMFS Headboat Survey (HBOAT) operated by the SEFSC Beaufort Laboratory, and the Texas Parks and Wildlife Recreational Fishing Survey (TXPWD). In 1998, 47% of the reported harvest of small coastal sharks came from MRFSS, 36% from TXPWD, and 17% from HBOAT.

Recreational catches in numbers peaked at about 187,000 fish in 2000 (Table 1). The recreational catches were dominated by the Atlantic sharpnose shark in all years (about 3/4 of the total catches in 1995 and 1998, and above 60% in 1996, 1997, 1999, and 2000), and bonnetheads were consistently the second-most important species caught recreationally from 1995-2000 (Table 2).

Recreational statistics from 1981-2000 revealed that the vast majority of small coastal sharks were caught in the Gulf of Mexico (60%) and South Atlantic (38%) regions, with only about 2% in the Mid-Atlantic region (Figure 6). Atlantic sharpnose sharks were caught in similar proportions in the South Atlantic and Gulf of Mexico regions during 1981-2000, whereas finetooth, bonnethead, and blacknose sharks were predominantly caught in the Gulf of Mexico region (Figures 7-10).

**Recreational Effort**

Recreational catch and effort information for sharks, including small coastal sharks, in the Atlantic and Gulf of Mexico is collected by the three surveys mentioned earlier (MRFSS, HBOAT, and TXPWD) and was reported in SB-III-5. Revised catch estimates for the SCS complex and for individual species, and estimates of non-targeted effort were included in Cortés (2000a) and are updated herein. MRFSS catch (type A and B1) estimates are for 1981-2000 and effort estimates are for 1981-1998, whereas those from HBOAT and TXPWD are for 1986-1999 (catch) and 1986-1998 (effort). Thus, for 1981-1985, catch and effort estimates are from MRFSS only, and from 1986-1999 (catch) and from 1986-1998 (effort), the estimates are the sum of estimates from the three surveys. Effort estimates are reported here as angler days (Cortés 2000a).

Recreational catches in numbers of the SCS complex peaked at 187,000 fish in 2000 (Table 3). Except for 1985, 1986, and 1990, when the bonnethead was the most frequently caught species, the Atlantic sharpnose shark was consistently the main species landed by recreational fishers, peaking at about 137,000 and 133,000 fish in 1991 and 1995, respectively. The bonnethead was also consistently the second-most caught species, with the importance of the blacknose and finetooth sharks alternating throughout the time series of catches. Recreational effort ranged from about 43 million angler days in 1981 to a maximum of over 64 million angler days in 1983, with the level of effort in the 1990's ranging from about 54 to 63 million angler days (Table 3).

## Average Size Information

Average size information for the SCS complex and for the four main species of SCS was obtained from several sources: the bottom-longline shark fishery observer program (BLLOP), the SEFSC's Trip Interview Program (TIP), and length frequency data from the three recreational surveys (MRFSS, HBOAT, TXPWD). Weights were predicted from lengths recorded in these surveys through length-weight relationships, and were transformed from whole to dressed by applying a conversion factor of 2. Average weights are presented in Tables 4-8.

Size information from the five surveys was generally dominated by data from Atlantic sharpnose shark. The directed shark fishery observer program (BLLOP) was available for 1993-2000 and primarily contained species-specific information for the Atlantic sharpnose and blacknose sharks (Tables 5 and 6). Size information from TIP–a data collection program initiated in the mid-1980's aimed primarily at collecting size frequency data from a variety of fisheries for stock assessment purposes–was available essentially for 1990-95, and contained little data for the bonnethead and blacknose shark and no data for the finetooth shark (Tables 6-8). Average weights predicted from MRFSS length data (1981-2000) were also dominated by Atlantic sharpnose shark and tended to be the lowest of all estimates for the SCS complex and for individual species (Tables 4-8). Observed weights, which were also available for most years, were always higher than predicted weights from this survey. In contrast, observed weights from the headboat survey (HBOAT) were in good agreement with the length-predicted weights for most years of observations (1986-98) for Atlantic sharpnose shark (which also made up the bulk of the observations) and the SCS complex. Finally, length-predicted average weights from TXPWD (1983-98) generally fell between those from MRFSS and HBOAT. This survey contained more length data for the bonnethead and the finetooth shark—but virtually no data—for the blacknose shark.

## Shrimp Trawl Bycatch in the U.S. South Atlantic Region

Estimates of the bycatch of small coastal sharks in the U.S. shrimp trawl fishery are essential for inclusion in this assessment because they are likely to exceed in importance the landings for these shark species. Bycatch data for the U.S. South Atlantic region (North Carolina, South Carolina, Georgia, and Florida) are gathered by the NMFS/Galveston Laboratory. Their characterization files include species-specific data available for 1992-1996. Effort data (number of trips) stratified by area and season were taken from Vaughan and Nance (1998).

### *Catch-per-effort information*

The unit of CPUE is catch per trip, which when multiplied by a measure of effort (total number of trips), yields total bycatch.

*Expansion to total number of sharks caught per tow and per trip and mean number of sharks caught per year*

The algorithm used to estimate the total number of sharks caught per tow (variable totalnum) from sharks observed in each sampled fraction of each tow was:

$$\text{totalnum} = \text{numb} * (\text{totwt}/\text{samwt}) * \text{totnet}$$

where numb = number of sharks of a given species observed in sampled fraction of tow; totwt = total weight of all catch in tow; samwt = total weight of sampled catch in tow (this was generally reported in the early years of observations, or, alternatively, calculated as the sum of the weights of all species sampled in a tow); and totnet = number of nets used in each tow (generally 2 or 4).

Sharks per tow were summed for all tows in a trip to get the number of sharks caught per trip. The number of sharks caught per trip was averaged to obtain the mean number of sharks by year, species, area, and season. Area strata were defined as in Vaughan and Nance (1998): FSO, Florida (south of 30° N latitude, outside); FGS, Florida (north) to South Carolina (outside); and NCI, North Carolina (inside). Seasonal strata were also defined as in Vaughan and Nance (1998): for Florida, Georgia, and South Carolina, winter included January-March; spring included April-June; summer included July-August; and fall included September-December. For North Carolina, winter included January-March; spring, April-May; summer, June-September; and fall, October-December.

*Expansion by trips to total number of sharks caught per area and season for each year and species*

The number of sharks of a given species caught per trip (CPT) was multiplied by the total number of trips within a stratum of area and season to obtain an estimate of bycatch in numbers for that stratum. Total number of trips by area and season strata for 1992-1996 was obtained from Vaughan and Nance (1998). Table 9 summarizes the expanded estimates of bycatch of bonnethead, Atlantic sharpnose, and finetooth sharks.

*Average size and age, and length-frequency distributions*

A total of 312 individual lengths, corresponding to 13 bonnetheads, 295 Atlantic sharpnose, and 3 finetooth sharks, were measured during the observed period (1992-1996). Length-frequency distributions (in cm total length) for the three species for each fishing year in which samples were available are shown in Table 10. Lengths were transformed into weights (kg) using available length-weight power relationships, and into ages, through existing Von Bertalanffy growth functions. All three finetooth sharks measured were very close to reported size at birth and thus were likely neonates; all Atlantic sharpnose sharks were age-0, many probably neonates, and bonnetheads were age-0 and age-1 (Tables 10 and 11).

## Shrimp Trawl Bycatch in the U.S. Gulf of Mexico Region

Estimates of small coastal shark bycatch in the shrimp fishery operating in the Gulf of Mexico were provided by S. Nichols (NMFS Pascagoula Lab., pers. comm.). These estimates are based on several sets of observer data. The Shrimp Bycatch Project, Turtle Incidental Catch Project, and Turtle Excluder Device Evaluations are combined into one set of "old" observer data that covers the period 1972-1982. In the early 1990's a new group of observer projects was initiated ("new" observer data) (S. Nichols, NMFS Pascagoula Laboratories, pers. comm.). Data are generally expansions to total catch per net from a single basket-and-shovel subsample. The "old" dataset was probably dominated by double-rigged vessels, whereas the "new" dataset was entirely dominated by quad-rigged vessels equipped with TEDs. To compensate in part for the lack of observer coverage in some years, data from the research trawl survey Oregon II are used to estimate catch rates through a GLM procedure that considers data stratified by year, season, area, depth, and source of data (commercial vs. survey). Annual bycatch is then estimated as the product of catch rate and total effort by stratum, the latter being provided by the NMFS/Galveston Laboratory. Since observer data are on a per net basis and shrimping effort estimates are on a per vessel basis, it was assumed that there were 2 nets per vessel, as recommended by the Reeffish Stock Assessment Panel (SAP) for red snapper. Variance estimates were not reported because more uncertainty results from the modeling approach than is contained in the data. The estimates provided used the "old" and "new" datasets combined. It is important to note that small coastal sharks are encountered much less frequently in the trawls than other species, such as red snapper, and therefore the estimates presented herein should be considered cautiously. Bycatch in 1999 was assumed to be the average of recent values for 1992-1997, divided by two, to account for the effect of TEDs. Bycatch in 2000 was assumed to equal that in 1999. Estimates of bycatch in numbers and weight for Atlantic sharpnose, bonnethead, and the small coastal shark aggregate are presented in Table 12.

# ANALYSIS OF CATCH RATE SERIES AND TRENDS

## Data Sources

A total of 41 catch rate series for small coastal sharks were examined (Appendix 1). Nine series were available for the small coastal shark complex, 13 for Atlantic sharpnose shark, 5 for bonnethead, 8 for blacknose shark, 5 for finetooth shark, and 1 for Atlantic angel shark. Some of the series presented herein are updates of those included in the 1998 Stock Evaluation Workshop report (SEW; NMFS 1998), but other series have not been examined before.

The available CPUE series are of different magnitude and quality: one is highly nominal (aggregated totals, Recreational), one represents an aggregated mean of set-by-set information (NMFS LL NE), some are standardized through simple GLM analyses designed to adjust for certain factors, such as area and season (NMFS LL PC, NMFS GN PC, Oregon II, NMFS Longline SE), and some operational variables (DGNOP). The series that were received without prior analysis were all subjected to the same standardization methodology (see CPUE standardization section below). In addition, the extent of the geographical and temporal coverage also varied among series.

**Fishery-independent Series**

**Southeast Area Monitoring and Assessment Program (SEAMAP).** Time series from this survey have been examined for the first time for the present stock assessment. The SEAMAP-South Atlantic Shallow Water Trawl Survey samples nearshore areas where commercial shrimping occurs along the southeastern coast of the U.S. between Cape Hatteras, North Carolina and Cape Canaveral, Florida (ASMFC 2000). Cruises are conducted in spring, summer, and fall. Estimates were available for small coastal sharks, Atlantic sharpnose, and bonnethead for the period 1989-2001. Trawl nets are towed for 20 minutes during daylight hours for this survey, and so catch rates are expressed on a tow basis. The survey uses a stratified random sampling design, where the strata correspond to different latitudinal areas and depth zones. The series were subjected to GLM analysis.

**South Carolina Department of Natural Resources Longline Survey (SC LL).** Two short series from this survey were presented in NMFS (1998), and are here updated and augmented to include the period 1995-2000. This survey utilizes monofilament longlines set in coastal waters of South Carolina. Surveys are conducted monthly from January to December. Estimates were available for small coastal sharks, Atlantic sharpnose, and blacknose shark. Catch rates are expressed on a set basis, which consists of 120 hooks on 6000 feet of mainline, with an average soak time of 0.75 hours (Glenn Ulrich, South Carolina Department of Natural Resources, pers. comm., and SB-III-9). The series were subjected to GLM analysis.

**Virginia Longline Survey (VIMS LL).** One series for Atlantic sharpnose (1974-1997) was presented in NMFS (1998). Two series are examined here for the period 1974-2001: an update of the Atlantic sharpnose and a new series for the small coastal aggregate. This survey utilizes longline gear set in coastal waters of Virginia. Several cruises, which typically cover 4 or 5 fixed stations, are run each year, mostly during the summer. Because sample sizes for some years were very low or no small coastal sharks were caught at all in some years, certain years had to be eliminated for the GLM analysis.

**Northeast Fisheries Science Center Bottom Trawl Survey (NEFSC Bottom Trawl).** Time series from this survey have been incorporated for the present stock assessment. The Northeast Fisheries Science Center in Woods Hole has been conducting spring and autumn bottom trawl surveys since 1968 and 1963, respectively. These surveys use stratified random sampling in depths ranging from 5 to 200 fathoms, from Cape Hatteras, North Carolina to well beyond the Canadian border. About 300 0.5-hour trawl sets are made at randomly chosen stations during each individual survey. Catch rates are thus expressed on a tow (=set) basis. The accumulated trawl survey data set contains information on over 27,000 sets. Some species of sharks susceptible to the bottom trawl gear are caught as bycatch in this survey. Estimates were available for Atlantic sharpnose, Atlantic angel, and the small coastal shark aggregate. The series were subjected to GLM analysis.

**Oregon II Groundfish Survey (Oregon II).** These series were presented in NMFS (1998), and are updated herein to include the period 1972-2000. Estimates include data for the small coastal shark aggregate, Atlantic sharpnose shark, and bonnethead. These series were derived from the Fall Resource Assessment Surveys conducted by the NMFS SEFSC

Pascagoula Laboratory, which catches sharks as bycatch. This research vessel survey consisted of many projects with varying seasonal and geographic coverage, with random or stratified random sampling, depending on the particular survey. A standard trawl gear was used in the vast majority of projects. The area of coverage includes portions of the western, central, and eastern Gulf of Mexico. The series were received after already having been subjected to GLM analysis (SAS GLM procedure; Gilmore Pellegrin, NMFS/Pascagoula, pers. comm.) and are expressed as numbers caught per hour, although they are also available in biomass units (pounds per hour).

**NMFS Narragansett Longline Survey (NMFS LL NE).** This survey is conducted out of the northeast region by personnel from the NMFS NEFSC Narragansett (Rhode Island) Laboratory. One series for the Atlantic sharpnose was reported in NMFS (1998) and is updated here to include 1986, 1989, 1991, 1996, 1998, and 2001. The 1996, 1998, and 2001 surveys were conducted at the same time of year (spring) as the 1989 and 1991 surveys, although there were some changes in gear between the two sets of years. The 1986 survey was conducted in the summer and, in the 1998 SEW, it was believed not to be comparable to the later years. The 2001 survey repeated 85 stations from the 1998 survey. This survey utilized monofilament longline gear deployed along the U.S. Atlantic coast, from Florida to southern New England. The data were not subjected to any GLM analysis for standardization; they represent annual averages, expressed as number of sharks caught per 100 hooks.

**NMFS Pascagoula Longline Survey (NMFS LL SE).** This coastal shark assessment survey is conducted out of the southeast region by personnel from the NMFS SEFSC Pascagoula (Mississippi) Laboratory. No data for small coastal sharks had been presented before. For this assessment, data for the Atlantic sharpnose were available for the U.S. South Atlantic (NMFS LL SE ATL; 1995-1997 and 2000), and eastern and western Gulf of Mexico (NMFS LL SE EGM and NMFS LL SE WGM; 1995-1997 and 1999-2000 for both). For blacknose shark, two series were available (eastern and western Gulf of Mexico, both for 1995-1997 and 1999-2000). For finetooth shark, only a short time series was available for the western Gulf of Mexico (1995, 1997, and 1999). This survey uses a standardized, random sampling design stratified by depth. Monofilament longlines are soaked for 1 hour. The nominal measure of CPUE is 100 hooks per hour. The area of coverage extends from the western Gulf of Mexico to North Carolina along the U.S. southeastern Atlantic seaboard. The series were received after already having been subjected to GLM analysis (SAS GLM procedure; Terry Henwood, NMFS/Pascagoula, pers. comm.)

**NMFS Panama City Longline Survey (NMFS LL PC).** This survey is conducted by personnel from the NMFS SEFSC Panama City (Florida) Laboratory in shallow, coastal areas of the northeastern Gulf of Mexico close to the Florida Panhandle. No data for small coastal sharks had been presented in NMFS (1998), but were reported recently by Carlson (2001a). Estimates from this survey were available for the small coastal shark aggregate, and for Atlantic sharpnose, blacknose, and finetooth for 1993-2000. This survey uses a standardized sampling design. Monofilament longlines are set at fixed stations monthly from April to October. Longlines are soaked for 1 hour. The series were subjected to GLM analysis (SAS GLM procedure; Carlson 2001a)

**NMFS Panama City Gillnet Survey (NMFS GN PC).** Like the previous survey, this survey is conducted by personnel from the NMFS SEFSC Panama City (Florida) Laboratory in shallow, coastal areas of the northeastern Gulf of Mexico close to the Florida Panhandle. No data for small coastal sharks had been presented in NMFS (1998), but were reported recently by Carlson (2001a). Estimates from this survey were available for the small coastal shark aggregate, and for Atlantic sharpnose, bonnethead, blacknose, and finetooth for 1996-2001. This survey uses a standardized sampling design. Monofilament gillnets with stretched mesh sizes ranging from 8.9 cm (3.5 inches) to 14.0 cm (5.5 inches) in steps of 1.3 cm (0.5 inches), are set at fixed stations monthly from April to October. Gillnets are soaked for 1 hour. The series were also subjected to GLM analysis (SAS GLM procedure; Carlson 2001a)

### Fishery-dependent Series

**Combined Recreational Series (Recreational).** Several new series of fishery-dependent data were created for the small coastal complex and the four individual species based on recreational catch and effort information collected by three surveys: the Marine Recreational Fishery Statistics Survey (MRFSS), the NMFS Headboat Survey (HBOAT), and the Texas Parks and Wildlife Department Survey (TXPWD), as reported in SB-III-5 and Cortés (2000). The measures of effort used to calculate CPUE were highly aggregated and non-targeted (see Recreational Effort section above). MRFSS catch (type A and B1) and effort estimates were for 1981-1998, whereas those from HBOAT and TXPWD were for 1986-1998. Thus, for 1981-1985, CPUE estimates were calculated from MRFSS data only, and from 1986-1998, the estimates correspond to data from the three surveys. This combined recreational series covered a wide area of the U.S. Gulf of Mexico and U.S. south and mid-Atlantic.

**Shark Drift Gillnet NMFS Observer Program (DGNOP).** Several new series of fishery-dependent data were created for the small coastal complex and the four individual species based on information from the commercial shark drift gillnet fishery NMFS SEFSC-operated observer program (DGNOP; Carlson 2001b). This directed fishery targets small coastal sharks from shore areas north of Key West, Florida north to Georgia. The fleet consists of a reduced number of vessels (typically 4-6) that use monofilament and multifilament gillnets allowed to drift at the surface to catch sharks (Carlson 2001b). Up to 14 species of sharks are landed in this fishery depending on season and area. Vessels fishing off the Central Florida and Georgia coasts during summer months tend to land sharks of the small coastal shark complex. Data were available for 1993-1995 and 1998-2001.

### CPUE Standardization Methodology

Standardized catch rates for the small coastal shark aggregate or individual species were developed using generalized linear mixed models for the data sets that were received without having been subjected to prior analysis (SC LL, VIMS LL, SEAMAP, and NEFSC Bottom Trawl). Because these data sets are from fishery-independent sources, where the methodology is standardized, many of the fishery operational variables that affect relative abundance estimates in analyses of fishery-dependent data sets needed not be included in the present analysis. Explanatory variables included in the data sets received for the present analysis typically included season, area, and depth. Note that because these surveys either do not target sharks specifically (SEAMAP and NEFSC Bottom Trawl) or contain a large proportion of sets with 0 catches or very low catches (Virginia LL), in some cases the data sets had to be truncated by eliminating levels of the explanatory variables (e.g., specific years) from the analysis to avoid over-parameterization of the model and lack of convergence of the algorithm. Final models thus typically contained few variables and no interaction terms were included because of the reasons given above.

The approach used to estimate relative abundance indices was a Generalized Linear Mixed Model that treats separately the proportion of sets with positive catches (i.e., where at least one shark was caught) assuming a binomial error distribution with a logit link function, and the catch rates of sets with positive catches assuming a Poisson error distribution with a log link function. The models were fitted with the SAS GENMOD procedure (SAS Institute Inc. 1999) using a forward stepwise approach in which each potential factor was tested one at a time. Initially, a null model was run with no explanatory variables (factors). Factors were then entered one at a time and the results ranked from greatest to smallest reduction in deviance per degree of freedom when compared to the null model. The factor which resulted in the greatest reduction in deviance per degree of freedom was then incorporated into the model if two conditions were met: 1) the effect of the factor was significant at least at the 5% level based on the results of a Chi-Square statistic of a Type III likelihood ratio test, and 2) the deviance per degree of freedom was reduced by at least 1% with respect to the less complex model. The year factor was always included because it is required for developing a time series.

Results were summarized in the form of deviance analysis tables including the deviance for proportion of positive observations and the deviance for the positive catch rates. Once the final model was selected, it was run with a computer program that utilizes the SAS GLIMMIX macro (which fits generalized linear mixed models using the SAS MIXED procedure; Wolfinger, SAS Institute Inc.). Goodness-of-fit criteria for the final model included Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion, and –2* the residual log likelihood (-2Res L). The significance of each individual factor was tested with a Type III test of fixed effects, which examines the significance of an effect with all the other effects in the model (SAS Institute Inc. 1999). The final mixed model calculated relative indices as the product of the year effect least squares means (LSMeans) from the binomial and Poisson components using bias correction terms to calculate confidence intervals.

**Trend Analysis**

Linear regressions were fitted to the CPUE series. The dependent variable (catch rate) was sometimes log-transformed to improve the fit between CPUE and time (independent variable). The positive or negative trend of the slope and whether it was significant was noted.

# LIFE HISTORY AND POPULATION BIOLOGY

## Vital Rates and Population Parameters

Vital rates of the four species of small coastal sharks were used to predict the productivity of the stocks. Estimates of productivity were then used in helping to define prior probability distributions in the Bayesian stock assessment section. To avoid the occurrence of negative values of the intrinsic rate of population increase (r), which can be obtained when using life tables (Cortés 1998; in press), only a modified demographic technique that ensures positive values of r was used. This method assumes that density dependence operates as increased survival during the pre-recruit stages and, like more conventional demographic approaches, models only the female portion of the population. A complete description of this technique and its application to shark populations can be found in Smith et al. (1998). In the present work, uncertainty in the estimates of vital rates was also incorporated through Monte Carlo simulation. Life history information for each species was obtained from the originally published studies and from the syntheses by Cortés (2000b; in press). New, unpublished information summarized in Carlson (2001c) was also considered.

Uncertainty in the estimates of age at maturity, maximum age, fecundity and survivorship was incorporated by randomly drawing values from assumed statistical distributions describing each of these vital rates, following in part the rationale used in Cortés (in press). Age at maturity was represented by a uniform distribution if a range was reported in the literature or by a triangular distribution if a single value was reported (in the case of the finetooth shark), with that value considered the likeliest and the lower and upper bounds obtained using ± 1 years as an approximation. Maximum age was represented by a linearly decreasing distribution scaled to a total relative probability of 1. The highest empirical value of lifespan reported in the literature was taken as the likeliest or maximum value and the minimum value was set by adding 30% to the likeliest value.

The probability of annual survival was estimated through five indirect life-history methods: 1) Pauly's (1980); 2) Chen and Watanabe's (1989); 3) Peterson and Wroblewski's (1984); and 4) and 5) Jensen's (1996) methods (see Cortés in press and references therein for a description of these methods). The lowest and highest estimates were used as bounds of a uniform distribution. Length-at-age and weight-at-age estimates were obtained from published von Bertalanffy growth functions and by transforming length into weight through published length-weight relationships, respectively.

Fecundity-at-age was represented by a normal distribution with the mean and standard deviation obtained from the literature. The normal distribution was further truncated to reflect the biological knowledge on litter size (i. e., the minimum and maximum litter sizes reported were used to bound the distribution). A uniform distribution was assumed when only a range was reported in the literature (in the case of the blacknose and sharpnose sharks). A 1:1 male to female ratio was assumed in all cases. The percentage of mature females at age was obtained from ogives presented in Carlson (2001c). Annual fecundity was expressed as the number of female offspring at birth divided by the length of the reproductive cycle in years.

A set of demographic traits (natural mortality, fecundity, age at maturity, and lifespan) was randomly selected from the probability distribution describing each individual trait and used as input to the modified demographic technique. The process was repeated 1,000 times (results tend to converge after only a few hundred iterations) for each of the four species analyzed and the mean and median r values were calculated. Confidence intervals for r were obtained as the 2.5th and 97.5th percentiles. All simulations were run using MS Excel spreadsheets equipped with proprietary add-in risk assessment software and the Visual Basic for Applications (VBA) language.

## STOCK ASSESSMENT

### Stock Assessment Models and Application

Several stock assessment models were used to evaluate the status of small coastal sharks using Bayesian statistical techniques.

*1. Bayesian Surplus Production Model using the SIR algorithm*

A nonequilibrium Schaefer biomass dynamic model was used to describe the population dynamics of exploited small coastal shark stocks. The discrete form of this logistic model is:

$$B_{t+1} = B_t + rB_t \frac{(1 - B_t)}{K} - C_t$$

Expected catch rates (CPUE) for each of the available time series were given by:

$$\hat{I}_t = qB_t e^{\varepsilon}$$

where $e^{\varepsilon}$ are the residual errors, which are lognormally distributed and have constant variance ($\varepsilon = N(0; \sigma^2)$). The estimates of model parameters ($B_{72}$, r, K, and q) are obtained by maximizing the likelihood function:

$$L(data \mid r, K, B_{72} / K, q) = \frac{1}{\sqrt{2\pi\hat{\sigma}}} \prod_t e^{\frac{-(\ln I_t - \ln \hat{I}_t)}{2\hat{\sigma}^2}}$$

where $L(data|r,K,B_{72}/K,q)$ is the likelihood of the data given the parameters, the product is over all years (t) for which catch rate data are available for all CPUE series, and $\sigma$ is the lognormal standard deviation of the error.

The geometric average of the time series of individual q estimates for each CPUE series was used as an analytic solution for the estimate of q that maximizes the likelihood function (Punt 1988; Hilborn and Mangel 1997):

$$\hat{q} = e^{\frac{1}{n}\sum(\ln I_t - \ln \hat{B}_t)}$$

where n is the number of years in each CPUE time series.

This form of the model assumes that all the $\sigma$s are equal and therefore represents an equal weighting scenario in which the single $\sigma$ is an estimable parameter with a uniform prior on the log scale (*weighting method 1*).

A slightly modified version of the model was also implemented in which each CPUE time series was weighted by the maximum likelihood estimate of the residual variance for each series ($\sigma^2$), which is given by:

$$\hat{\sigma}^2 = \sum_t \frac{(\ln I_t - \ln \hat{I}_t)^2}{n}$$

where n is again the number of years in each CPUE time series (*weighting method 2*).

Performance indicators included the maximum sustainable yield (MSY=rK/4), the stock biomass in the last year of data ($B_{2001}$), and the ratio of stock biomass in the last year of data to carrying capacity ($B_{2001}/K$).

Numerical integration was carried out using the sampling/importance resampling (SIR) algorithm (Berger 1985, McAllister and Kirkwood 1998, McAllister et al. 2001). 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, as described in McAllister and Kirkwood (1998; equation 20, p. 1043). 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 (McAllister and Kirkwood 1998; equation 21, p. 1043). The importance function used in the SIR algorithm was the joint prior pdf of $\theta$ (vector of parameter estimates K, r, $B_{72}/K$, and q). This model was implemented in MS Excel and the VBA language. The functions used to generate random variables came from the Excel add-in, PopTools (Hood 2000), which uses DLL functions originally written in Pascal in the TPMath numeric library. One million iterations were run for each model implementation.

*2. Bayesian Surplus Production Model using State-Space methodology and the Gibbs sampler*

A nonequilibrium Schaefer surplus production model was also used to describe the population dynamics of exploited small coastal shark stocks using a Markov Chain Monte Carlo (MCMC) method for numerical integration. This was done following the model of Meyer and Millar (1999a), originally developed in BUGS, and recoded in WINBUGS (Spiegelhalter et al. 2000). In this approach, a state-space model accounts for both process error and observation error in a unified analytical framework that uses a MCMC method called Gibbs sampling (Gilks et al. 1996) to sample from the joint posterior distribution.

State-space models can be used to relate observed catch rates ($I_t$) to unobserved states (biomass, $B_t$) through a stochastic observation model for $I_t$ given $B_t$. A description of state-space models can be found in Meyer and Millar (1999b) and Millar and Meyer (1999). Millar and Meyer (1999a) implemented a nonlinear, nonnormal state-space model assuming lognormal error structures and a reparametrization by expressing the annual biomass as a proportion of carrying capacity ($P_t = B_t/K$). This Bayesian model includes the joint prior distribution of all unobservable quantities, i.e., K, r, q, $\sigma^2$ (process error variance), and $\tau^2$ (observation error variance) and the unknown states $P_1,\ldots,P_N$, and the joint distribution of the observable quantities, i.e., the CPUE indices $I_1,\ldots,I_N$. Bayesian inference then uses the posterior distribution of the unobserved quantities given the data (see Meyer and Millar 1999a for a full description of the model). As in the original model developed by Millar and Meyer (1999a), the present implementation used an inverse gamma distribution as a prior for $\sigma^2$, $\tau^2$ (one prior for each individual CPUE series), and q (also one prior for each individual CPUE series).

Performance indicators used included the maximum sustainable yield (MSY=rK/4), the fishing mortality at MSY ($F_{MSY}$=r/2), the biomass at MSY ($B_{MSY}$=K/2), the stock biomass in the last year of data ($B_{2001}=P_{2001}*K$), the ratio of stock biomass in the last year of data to carrying capacity ($B_{2001}/K$), the ratio of fishing mortality in the current year to $F_{MSY}$ ($F_i/F_{MSY}$), and the ratio of stock biomass in the current year to $B_{MSY}$ ($B_i/B_{MSY}$).

All runs carried out with WINBUGS were based on two chains of initial values (where the $P_t$ values were set equal to 0.5 and 1.0, respectively; see Appendix 2) 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.

*3. Bayesian LRSG Model using State-Space methodology and the Gibbs sampler*

A lagged recruitment, survival and growth (LRSG) model (Hillborn and Mangel 1997) was also used to model the dynamics of small coastal shark stocks. This model is an approximation of the delay-difference model of Deriso (1980) and can be expressed in its discrete form as:

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

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

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

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

The parameters a and b are defined as:

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

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

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

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

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

and

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

Other performance indicators included the ratio of stock biomass in the current year to $B_{MSY}$ ($B_i/B_{MSY}$), the exploitation rate in the current year (exploitation rate=$C_i/B_i$), the harvest rate to produce MSY ($H_{MSY}$=MSY/ $B_{MSY}$), and the ratio of harvest rate in the current year to $H_{MSY}$ (Hratio=exploitation rate/ $H_{MSY}$).

The model was also implemented in WINBUGS. As with the SPM, all runs were based on two chains of initial values (where the $B_t$ values were set equal to low and high values, respectively) to account for over-dispersed initial values, and included a 5,000 sample burn-in phase followed by a 100,000 iteration phase. This implementation of the LRSG model was also a state-space model that accounted for both process and observation errors. As with the implementation to the surplus production model detailed above, observed catch rates ($I_t$) were related to unobserved states (biomass, $B_t$) through a stochastic observation model for $I_t$ given Bt. The nonlinear, nonnormal state-space model also assumed lognormal error structures, but no reparametrization, i.e., the annual biomass ($B_t$) was used directly. The joint prior distribution of all unobservable quantities, i.e., $B_0$, z, s, q, $\sigma^2$ (process error variance), and $\tau^2$ (observation error variance) and the unknown states $B_1,\ldots,B_N$, and the joint distribution of the observable quantities, i.e., the CPUE indices $I_1,\ldots,I_N$ were modeled.

*Convergence diagnostics*

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

*Prior probability distributions for the base-case scenario*

*Methods 1 and 2 (Bayesian Surplus Production Models)*

**Small coastal shark aggregate.—**The prior chosen for K in the base-case scenario was uninformative, as little is known about the carrying capacity of shark populations. The prior distribution was uniform on the log of K over the range $5\times10^6$ to $150\times10^6$ lb dw. This prior is proportional to the inverse of K and so assigns less credibility to higher values of K (McAllister and Kirkwood 1998). The lower bound of this distribution was set approximately equal to the largest "observed" catch in the time series for the small coastal shark aggregate, and the average and maximum catch in the time series represent about 1.7% and 3.8%, respectively, of the upper bound.

An informative prior was used for r, based in part on the results obtained from life table Monte Carlo simulation (see above) and also on the values of r used in the assessment of large coastal shark stocks (NMFS 1998, McAllister et al. 2001). A lognormal pdf with mean=0.07 and

SD=0.014 (or SD=0.20 in the logarithm of r for the lognormal pdf) was used in the base-case scenario for small coastal sharks. The SD in the logarithm of r ($\sigma_r$) for the lognormal pdf is calculated as (McAllister et al. 2001):

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

This pdf makes values of r<0 impossible and concentrates most of the density towards the lower values. An informative prior was also used to describe the ratio of the stock biomass in 1972 with respect to K ($P_{72}$), with mean=1 and SD in the logarithm of r of 0.20. This prior reduces the probability that $P_{72}$ will be much higher than K since most of the values will be closer to unity (McAllister et al. 2001).

**Atlantic sharpnose shark.—**The prior distribution was uniform on the log of K over the range $5x10^6$ to $100x10^6$ lb dw. The lower bound of this distribution was set approximately equal to the largest "observed" catch in the time series for the Atlantic sharpnose shark, and the average and maximum catch in the time series represent about 1.9% and 5%, respectively, of the upper bound. A lognormal pdf was used for the prior of r, with mean=0.08 and SD=0.20 (in the logarithm of r for the lognormal pdf). A lognormal pdf was also used for the prior of $P_{72}$, with mean=1 and SD in the logarithm of r of 0.20.

**Bonnethead.—**The prior distribution was uniform on the log of K over the range $1x10^6$ to $40x10^6$ lb dw. The lower bound of this distribution was set approximately equal to the largest "observed" catch in the time series for the bonnethead, and the average and maximum catch in the time series represent about 1.1% and 1.7%, respectively, of the upper bound. A lognormal pdf was used for the prior of r, with mean=0.10 and SD=0.20 (in the logarithm of r for the lognormal pdf). A lognormal pdf was also used for the prior of $P_{72}$, with mean=1 and SD in the logarithm of r of 0.20.

**Blacknose shark.—**The prior distribution was uniform on the log of K over the range $0.5x10^6$ to $25x10^6$ lb dw. The lower bound of this distribution was set approximately equal to twice the largest "observed" catch in the time series for the blacknose shark, and the average and maximum catch in the time series represent about 0.3% and 1.1%, respectively, of the upper bound. A lognormal pdf was used for the prior of r, with mean=0.06 and SD=0.20 (in the logarithm of r for the lognormal pdf). A lognormal pdf was also used for the prior of $P_{72}$, with mean=1 and SD in the logarithm of r of 0.20.

**Finetooth shark.—**The prior distribution was uniform on the log of K over the range $0.5x10^6$ to $20x10^6$ lb dw. The lower bound of this distribution was set approximately equal to twice the largest "observed" catch in the time series for the blacknose shark, and the average and maximum catch in the time series represent about 0.4% and 1.4%, respectively, of the upper bound. A lognormal pdf was used for the prior of r, with mean=0.06 and SD=0.20 (in the logarithm of r for the lognormal pdf). A lognormal pdf was also used for the prior of $P_{72}$, with mean=1 and SD in the logarithm of r of 0.20.

*Method 3 (Bayesian LRSG Model)*

**Small coastal shark aggregate.—**In the base-case scenario, an uninformative prior was chosen for the steepness parameter, z, i.e., a uniform distribution ranging from 0.2 (theoretical minimum) to 0.9. The prior chosen for s (the parameter combining survivorship and growth) in the base-case scenario was also uninformative. A uniform distribution ranging from 0.60 to 0.95 was assumed for s, based on the rates of annual survivorship used to calculate intrinsic rates of increase (Table 25) and on growth information for small coastal sharks. The time lag between birth and recruitment to the fishery (L) was set at 4 years for the small coastal shark aggregate, based on the estimated ages at maturity for the individual species. The prior for the virgin biomass ($B_0$) was uniform on the log of K over the range $5 \times 10^6$ to $150 \times 10^6$ lb dw as in the base-case scenario for the surplus production models (methods 1 and 2).

**Atlantic sharpnose shark.—**The prior distribution for z was uniform over the range 0.2-0.9, the prior for s was uniform over the range 0.60-0.90, L was set at 3 years, and the prior for $B_0$ was uniform on the log of K over the range $5 \times 10^6$ to $100 \times 10^6$ lb dw as in the base-case scenario for the surplus production models.

**Bonnethead.—**The prior distribution for z was uniform over the range 0.2-0.9, the prior for s was uniform over the range 0.50-0.90, L was set at 3 years, and the prior for $B_0$ was uniform on the log of K over the range $1 \times 10^6$ to $40 \times 10^6$ lb dw as in the base-case scenario for the surplus production models.

**Blacknose shark.—** The prior distribution for z was uniform over the range 0.2-0.9, the prior for s was uniform over the range 0.65-0.95, L was set at 4 years, and the prior for $B_0$ was uniform on the log of K over the range $0.5 \times 10^6$ to $25 \times 10^6$ lb dw as in the base-case scenario for the surplus production models.

**Finetooth shark.—** The prior distribution for z was uniform over the range 0.2-0.9, the prior for s was uniform over the range 0.60-0.90, L was set at 4 years, and the prior for $B_0$ was uniform on the log of K over the range $0.5 \times 10^6$ to $20 \times 10^6$ lb dw as in the base-case scenario for the surplus production models.

*Sensitivity Analysis*

All sensitivity tests were performed using Method 2 (Bayesian SPM with state-space methodology and the Gibbs sampler) and Method 3 (Bayesian LRSG using state-space methodology and the Gibbs sampler) and incorporated a number of modifications to the base-case scenario, which used the priors described above for the small coastal shark aggregate and the individual species.

*Bayesian State-Space SPM*

**Small coastal shark aggregate.—**Sensitivity trials (summarized in Table 26) included: using the 9 original CPUE series from the base-case scenario, but scaled (divided by the mean; scenario 1); eliminating each of the 9 catch rate series one at a time (scenarios 2-10); using a uniform pdf directly on K (scenario 11); changing the mean value of r to 0.15, 0.10, and 0.05, respectively (scenarios 12, 13, and 14); bounding the prior for $P_{72}$ from 0.5 to 2.0, and from 0.1 to 2.0, respectively (scenarios 15 and 16); and changing the range of the prior uniform on the log of K to $5x10^6$ to $60x10^6$ lb dw (scenario 17).

**Atlantic sharpnose shark.—**Sensitivity trials (summarized in Table 27) included: using the 13 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 13 catch rate series one at a time (scenarios 2-14); using a uniform pdf directly on K (scenario 15); changing the mean value of r to 0.20, 0.10, and 0.05, respectively (scenarios 16-18); bounding the prior for $P_{72}$ from 0.5 to 2.0 (scenario 19); and changing the range of the prior uniform on the log of K to $5x10^6$ to $40x10^6$ lb dw (scenario 20).

**Bonnethead.—**Sensitivity trials (summarized in Table 28) included: using the 4 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 4 catch rate series one at a time (scenarios 2-5); using a uniform pdf directly on K (scenario 6); changing the mean value of r to 0.20, 0.10, and 0.05, respectively (scenarios 7-9); bounding the prior for $P_{72}$ from 0.5 to 2.0 (scenario 10); and changing the range of the prior uniform on the log of K to $1x10^6$ to $20x10^6$ lb dw, and $1x10^6$ to $60x10^6$ lb dw, respectively (scenarios 11 and 12).

**Blacknose shark.—**Sensitivity trials (summarized in Table 29) included: using the 7 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 7 catch rate series one at a time (scenarios 2-8); changing the mean value of r to 0.12 and 0.03, respectively (scenarios 9-10); changing the range of the prior uniform on the log of K to $0.5x10^6$ to $40x10^6$ lb dw and $0.5x10^6$ to $60x10^6$ lb dw, respectively (scenarios 11-12), and setting the catch in 1984, 1985, 1990, and 1991 (which was 0 in the base-case scenario) equal to the mean of the non-zero catch during 1983-1994 (scenario 13).

**Finetooth shark.—**Sensitivity trials (summarized in Table 30) included: using the 5 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 5 catch rate series one at a time (scenarios 2-6); changing the mean value of r to 0.12 and 0.03, respectively (scenarios 7-8); changing the range of the prior uniform on the log of K to $0.5x10^6$ to $40x10^6$ lb dw and $0.5x10^6$ to $60x10^6$ lb dw, respectively (scenarios 9-10), and setting the catch in 1990 (which was 0 in the base-case scenario) equal to the mean of the non-zero catch during 1986-1994 (scenario 11).

*Bayesian State-Space LRSG model*

**Small coastal shark aggregate.—**Sensitivity trials (summarized in Table 31) included: using the 9 original CPUE series from the base-case scenario, but scaled (divided by the mean; scenario 1); eliminating each of the 9 catch rate series one at a time (scenarios 2-10); changing the range of the prior uniform on the log of $B_0$ to $5x10^6$ to $60x10^6$ lb dw (scenario 11); changing the range for s to 0.40-0.75 (scenario 12); changing the range for z to 0.20-0.60 and 0.20-0.40 (scenarios 13-14); changing the time lag to 5 years (scenario 15), using a CPUE series obtained from the NMFS GN PC as a recruitment index (scenario 16), setting the bycatch estimates from the South Atlantic in all missing years equal to the mean of the years for which there were estimates (scenario 17), and assuming no bycatch at all in the South Atlantic for any years (scenario 18).

**Atlantic sharpnose shark.**—Sensitivity trials (summarized in Table 32) included: using the 13 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 13 catch rate series one at a time (scenarios 2-14); changing the range of the prior uniform on the log of $B_0$ to $5x10^6$ to $40x10^6$ lb dw (scenario 15); changing the range for s to 0.40-0.70 (scenario 16); changing the range for z to 0.20-0.60 and 0.20-0.40 (scenarios 17-18); changing the time lag to 4 years (scenario 19), using a CPUE series obtained from the NMFS GN PC as a recruitment index (scenario 20), setting the bycatch estimates from the South Atlantic in all missing years equal to the mean of the years for which there were estimates (scenario 21), and assuming no bycatch at all in the South Atlantic for any years (scenario 22).

**Bonnethead.**—Sensitivity trials (summarized in Table 33) included: using the 4 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 4 catch rate series one at a time (scenarios 2-5); changing the range of the prior uniform on the log of $B_0$ to $1x10^6$ to $20x10^6$ lb dw (scenario 6); changing the range for s to 0.30-0.70 (scenario 7); changing the range for z to 0.20-0.60 and 0.20-0.40 (scenarios 8-9); changing the time lag to 4 years (scenario 10), setting the bycatch estimates from the South Atlantic in all missing years equal to the mean of the years for which there were estimates (scenario 11), and assuming no bycatch at all in the South Atlantic for any years (scenario 12).

**Blacknose shark.**—Sensitivity trials (summarized in Table 34) included: using the 7 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 7 catch rate series one at a time (scenarios 2-8); changing the range of the prior uniform on the log of $B_0$ to $5x10^6$ to $40x10^6$ lb dw and $5x10^6$ to $60x10^6$ lb dw, respectively (scenarios 9-10); changing the range for s to 0.45-0.75 (scenario 11); changing the range for z to 0.20-0.60 and 0.20-0.40 (scenarios 12-13); changing the time lag to 5 years (scenario 14), and setting the catch in 1984, 1985, 1990, and 1991 (which was 0 in the base-case scenario) equal to the mean of the non-zero catch during 1983-1994 (scenario 15).

**Finetooth shark.**—Sensitivity trials (summarized in Table 35) included: using the 5 original CPUE series from the base-case scenario, but scaled (scenario 1); eliminating each of the 5 catch rate series one at a time (scenarios 2-6); changing the range of the prior uniform on the log of $B_0$ to $5x10^6$ to $40x10^6$ lb dw and $5x10^6$ to $60x10^6$ lb dw, respectively (scenarios 7-8); changing the range for s to 0.40-0.70 (scenario 9); changing the range for z to 0.20-0.60 and 0.20-0.40 (scenarios 10-11); changing the time lag to 5 years (scenario 12), and setting the catch in 1990 (which was 0 in the base-case scenario) equal to the mean of the non-zero catch during 1986-1994 (scenario 13).

## RESULTS AND DISCUSSION

### Standardized Catch Rates

**SEAMAP Indices.** About 52%, 46%, and 25% of the tows analyzed encountered small coastal sharks, Atlantic sharpnose shark, and bonnethead, respectively. The proportion of positive catches for the small coastal shark aggregate and Atlantic sharpnose was explained in each case by the month, area, and year factors in that order (Tables 13-14), whereas for bonnethead the order of the factors was area, month, and year (Table 15). The mean catch rates for positive catches were also explained by the same factors in the same order for the SCS aggregate and Atlantic sharpnose (Tables 13 and 14), and by area, year, and month for bonnethead (Table 15). All factors in the final model were significant (Tables 13-15). The relative standardized catch rates mirrored the nominal values well for the three series, with only the 1991 nominal value for small coastal sharks falling outside the 95% confidence limits of the standardized value for that year (Figure 11).

**SC LL Indices.** Months were pooled into seasons (winter, spring, summer, and fall), but sampling locations were too numerous to include in the analysis and the information needed to pooled them into a more reduced number of areas to allow standardization of catch rates did not arrive in time to be considered for the present assessment. Thus the area factor was not included in the analysis. About 81%, 79%, and 32% of the sets analyzed encountered small coastal sharks, Atlantic sharpnose shark, and blacknose shark, respectively. The proportion of positive catches for the small coastal aggregate, and for Atlantic sharpnose and blacknose sharks was explained in each case by the season and year factors in that order (Tables 16-18). The mean catch rates for positive catches were also explained by the same factors in the same order. Despite not being significant (P=0.0787; Table 18), the year factor for blacknose shark was included to develop the time series. Factors in the final model were significant, except for the year factor in the final model for positive catches for small coastal sharks, Atlantic sharpnose shark, and blacknose shark, respectively (Tables 16-18). The year factor in the final model for proportion of positive catches was also barely not significant for the blacknose shark (P=0.0550; Table 18). The relative standardized catch rates showed trends similar to those of the nominal values for the three series, with all nominal values falling inside the 95% confidence limits of the standardized series (Figure 12).

**VIMS LL Indices.** Several years (1978, 1979, 1982, 1984-1986, and 1994) and one area (B2) were eliminated from the analysis because there were no observations of trips with positive catches in those years and area, which resulted in the algorithm for CPUE standardization not being able to converge. The natural log of the number of hooks divided by the number of soak hours was used as an offset in the model with the Poisson error distribution for positive catches because the set duration and number of hooks used per set was variable in the data set. Months were also pooled into seasons (winter, spring, summer, and fall) to allow standardization of catch rates. The analysis for the small coastal shark aggregate included mostly Atlantic sharpnose sharks. About 22% of the sets analyzed encountered small coastal sharks and Atlantic sharpnose shark, respectively. The proportion of positive catches for the small coastal aggregate and for Atlantic sharpnose shark was explained in each case by the area, season, and year factors in that order (Tables 19-20), and the year factor was included despite not being significant (P=0.5050 in both cases; Tables 19-20) to develop time series. For the small coastal shark aggregate, the mean catch rate for positive catches was explained by the year and season factors, but the area factor was eliminated from the final model because it did not meet the criterion of at least 1% reduction in deviance per degree of freedom (Table 19). For Atlantic sharpnose shark, only the season factor explained the mean catch rate for positive catches; the area factor did not meet the reduction in deviance per degree of freedom criterion, and the year factor was included to develop the time series despite not meeting that criterion either.

The area and season factors in the final models for the proportion of sets with positive catches were significant, but not the year factor (Tables 19-20). For the sets with positive catches neither the year nor season (small coastal shark aggregate), and neither the season nor year (Atlantic sharpnose shark) factors were significant (Tables 19-20). The relative standardized catch rates showed trends similar to those of the nominal values for the two series. All nominal values fell inside the 95% CL of the standardized series, but those limits were very wide due to high variability in any given year probably as a result of low number of observations (Figure 13).

**NEFSC Bottom Trawl.** Several years of data, and depth zones or seasons, were eliminated from the analyses because there were no observations of sets with positive catches in strata corresponding to those factors. This resulted in the algorithm for CPUE standardization not being able to converge. Months were also pooled into seasons (winter, spring, summer, and fall) to allow standardization of catch rates. For the analysis of the small coastal shark aggregate, years 1963-1967 and depth zones 2 and 5 were eliminated; for Atlantic angel shark, years 1963-1967 were removed; and for Atlantic sharpnose shark, years 1963-1973, 1975-1977, and 1986, and the spring and fall seasonal factors were eliminated to allow for the analysis to proceed. Only about 3.4%, 3.7%, and 2.1% of the sets analyzed encountered small coastal, Atlantic sharpnose, and Atlantic angel sharks, respectively.

The proportion of positive catches for the small coastal shark aggregate and for Atlantic sharpnose shark was explained by the depth zone, season, and year factors in that order (Tables 21-22), whereas for Atlantic angel shark the order of the explanatory variables was season, year, and depth zone (Table 23). For the small coastal shark aggregate and Atlantic sharpnose shark, the mean catch rate for positive catches was explained by the depth zone, year, and season factors (Tables 21-22), whereas for Atlantic angel shark it was explained by the season, year, and depth zone factors (Table 23). In the final mixed models for proportion of positive catches, all tests of fixed effects were highly significant. In contrast, in the final mixed models for positive catches season was not significant for the small coastal shark aggregate and Atlantic sharpnose shark (Tables 21-22), and year was not significant for the Atlantic sharpnose (Table 22) and Atlantic angel shark (barely not significant at the 5% level in the latter; Table 23).

For the small coastal shark aggregate, the trend of the relative standardized catch rates was substantially different from that of the nominal values during the early part of the time series, and from 1978 to 1983 the nominal values did not fall within the 95% CL of the standardized values (Figure 14). The trends of the standardized vs. nominal series for Atlantic sharpnose and Atlantic angel sharks were much more similar, and only the 1978-1983 nominal values for Atlantic sharpnose shark fell outside the 95% CL of the corresponding standardized values. For the three time series, the proportion of sets with positive catches was very low in most years due to the very large number of tows conducted in this survey and the relative scarcity of small coastal sharks as bycatch.

**Trend Analysis**

Five of the nine series available for the small coastal shark aggregate showed a declining trend in catch rates, but only the Oregon II and the NEFSC Trawl survey series were statistically significant both at the 1% level (Table 24). Of the four series that showed a positive trend, only the Combined Recreational (1% level) and the DGNOP series were statistically significant (5% level). None of the slopes were very steep: the largest statistically significant annual rates of decrease and increase were about 2% and 6%, respectively.

Five of the thirteen series for Atlantic sharpnose shark exhibited a declining trend, but only the Oregon II series had a significantly negative slope (5% level). Of the eight series showing a positive trend, only the Combined Recreational series had a significantly positive slope (1% level), which was also the steepest significant slope (6%). For bonnethead, three of the five series exhibited negative slopes, one of which (the Oregon II series) was very highly significant and had the steepest slope (13%) of any of the 41 series examined. Of the eight series available for blacknose shark, five had positive slopes, but none of the eight slopes was statistically significant. For finetooth shark, three of the five series had positive slopes, but only that for the DGNOP series was significant (at the 5% level). For Atlantic angel shark, the only series available (NEFSC Trawl survey) had a highly significantly negative slope (P=0.0001; Table 24).

In all, the trends for small coastal sharks and individual species were rather flat as evidenced by the general lack of steepness of the slopes. If we accept that these catch rate series reflect the relative abundance of the stocks we can infer that these stocks have remained fairly stable during the exploitation phase.

**Vital Rates and Population Parameters**

The relative magnitude of the r values obtained through the modified demographic technique incorporating uncertainty in vital rates is in line with the patterns found by Smith et al. (1998) using a deterministic approach and those found by Cortés (in press) through Monte Carlo simulation of life tables and matrix population models, and by Cortés (2000b) through multivariate analysis of life history traits. In essence, the bonnethead and the Atlantic sharpnose shark are the most productive of the small coastal species, with the blacknose and finetooth sharks being less productive and closer to other large coastal sharks—such as the blacktip shark—in the spectrum of life-history traits and population characteristics along which shark species can be placed (Cortés 2000, in press; Smith et al. 1998).

Table 25 summarizes the input biological data and output r values for the four small coastal shark species. Mean r values ranged from 0.037 $yr^{-1}$ for the blacknose shark to 0.064 $yr^{-1}$ for the bonnethead. It is important to note that estimates of r for large coastal shark species obtained using this methodology (Cortés, unpublished data) are lower than those reported herein for small coastal shark species. In that respect, the base estimate of $r=0.11\ yr^{-1}$ used in the assessment of the large coastal shark aggregate (NMFS 1998), which was arrived at through "expert opinion" and was based in part on results of life tables assuming density independence, should be regarded as high from a theoretical standpoint. However, the r values of biomass dynamic models used in many stock assessments incorporate density-dependent considerations and can also accommodate processes such as emigration or immigration to circumvent the assumption of closed populations implicit in these methods. Small coastal sharks, however, are not as migratory as their large coastal counterparts and so the estimates of r obtained herein should be regarded as the "best" that can be obtained at this time assuming density dependence and based on our knowledge of the vital rates of these species.

**Model Projections and Resource Status**

Results of the base-case and alternative scenarios indicate that the current level of removals is sustainable for the small coastal shark aggregate and the individual species. The posterior distributions of K for the small coastal aggregate and Atlantic sharpnose obtained through the Bayesian state-space SPM are considerably skewed to the left and truncated on the right side, suggesting that the upper bound for K has more influence on the posterior than the lower bound (Figures 15 and 17). The posterior of K for the bonnethead and blacknose shark is more normal (Figures 19 and 21), whereas the posterior of K for the finetooth shark is skewed to the right, suggesting that the lower bound of K has more influence on the posterior than the upper bound (Figure 23). Posterior distributions for all other parameters were much more normal and exhibited varying degrees of skewness to the right.

The posterior distributions of several population parameters and management quantities obtained through the Bayesian state-space LRSG model showed varying degrees of skewness and truncation. For the small coastal aggregate and Atlantic sharpnose, the posterior for the virgin biomass, $B_0$, ended abruptly near the right tail of the distribution (Figures 25 and 27, respectively), whereas the posteriors for bonnethead, blacknose, and finetooth were more normal (Figures 29, 31, and 33), although skewed to the right, especially for the finetooth shark. The posterior for the parameter incorporating survival and growth, s, favored higher values for both the small coastal aggregate and Atlantic sharpnose (Figures 25 and 27), and lower values for the bonnethead, blacknose, and finetooth (Figures 29, 31, and 33). The posterior for the steepness parameter, z, also tended to indicate that higher values were favored (although the theoretical maximum is 1), ending abruptly on the right side for the small coastal aggregate (Figure 25), bonnethead (Figure 29), and especially for the Atlantic sharpnose (Figure 27). For blacknose and finetooth, the posterior for z was more uniform, but did not end smoothly at the tails, reflecting the bounds imposed on that parameter. All posteriors for the other parameters were much more normal, exhibiting varying degrees of skewness to the right as with the Bayesian state-space SPM analysis.

Relative stock biomass and fishing mortality trajectories obtained with the Bayesian state-space SPM for the small coastal aggregate and Atlantic sharpnose followed similar trends, since the catches were dominated by this species. Relative biomass ($B/B_{MSY}$) in any given year from 1972-2000 was estimated by the model to be above 1, meaning that the stock biomass in any given year exceeded that producing MSY (Figures 16 and 18). Relative fishing mortality ($F/F_{MSY}$) was generally below 1, but there were several years for the small coastal aggregate (Figure 16) and two years (1992 and 1993) for Atlantic sharpnose (Figure 18) when the fishing mortality on the stock was estimated to exceed that which would produce MSY. The phase plots (default MSY control rule; Restrepo et al. 1998) of relative biomass vs. relative fishing mortality trajectories further show that in most years the stock biomass was above—and the fishing mortality, below—that producing MSY for the small coastal aggregate and Atlantic sharpnose (Figures 16 and 18, respectively). For bonnethead, all values of biomass were well above that producing MSY, and only in 1995 was fishing mortality estimated to exceed that producing MSY (Figure 20). For blacknose, all values of biomass were above that producing MSY and all values of F were below that producing MSY (Figure 22). For finetooth, the values of F in the final five years of the series were estimated by the model to be above the F producing MSY (Figure 24).

Relative biomass trajectories and relative fishing mortalities estimated through the Bayesian state-space LRSG model showed similar patterns to those estimated with the Bayesian state-space SPM, but the scales differed. Predictions of both relative biomass and relative harvest rate ($H/H_{MSY}$) from the Bayesian LRSG model tended to be higher for the small coastal aggregate (Figure 26). For Atlantic sharpnose and bonnethead (Figures 28 and 30), relative biomass was higher, and relative harvest rates, lower. For blacknose, relative biomass was higher, but relative harvest rate was very similar, with the 97.5th percentile being higher in the Bayesian LRSG model (Figure 32). For finetooth, relative biomass was higher, and relative harvest rate tended to be lower in the Bayesian LRSG model (Figure 34).

*Sensitivity analysis*

The expected posterior mean values, CVs, and 2.5th and 97.5th percentiles of the base-case and alternative scenarios for the small coastal aggregate, Atlantic sharpnose, bonnethead, blacknose, and finetooth are given in Tables 26-30, respectively, for the two Bayesian SPMs, and in Tables 31-35, respectively, for the Bayesian LRSG model.

For the small coastal aggregate and Atlantic sharpnose, results of the base-case scenario were most similar for the Bayesian SPM using the SIR algorithm with the MLE estimate of variance for each series (weighting method 2) and the Bayesian SPM using the Gibbs sampler (Tables 26 and 27). For the bonnethead, blacknose, and especially for finetooth, the SIR algorithm using weighting method 1 (equal weighting scenario) sometimes provided closer estimates to those from the Gibbs sampler than weighting method 2 (Tables 28-30). Predictions from all models in all cases ultimately indicated that the stock biomass at the beginning of 2001 was above half the carrying capacity of the stock, or, in other words, above the stock size producing MSY (except for the SPM using weighting method 1 for the finetooth, which was slightly below MSY). Predictions from the Bayesian LRSG were generally similar to those obtained with the various SPMs, except that predictions of MSY were much higher and predictions of $B_{MSY}$, lower, which is directly a result of the way MSY and $B_{MSY}$ are calculated in each method (Tables 31-35).

*Bayesian State-Space SPM*

For the small coastal aggregate, using the scaled series decreased the predictions of K, MSY, biomass in 2001 ($B_{2001}$), and $B_{2001}/K$ (scenario 1; Table 26). The SC LL catch rate series had the largest effect of any of the CPUE series, and eliminating it reduced the predictions of K, MSY, $B_{2001}$, and $B_{2001}/K$ with respect to those obtained in the base-case scenario (Table 26). As expected, increasing the prior value of r (scenarios 12 and 13) decreased the expected value of K, since these two parameters are negatively correlated. The expected value of MSY also increased considerably, but the values of $B_{2001}$ varied very little in these two scenarios. Reducing the prior value of r (scenario 14) had little effect on the expected value of K, but considerably reduced the expected value of MSY while having very little effect on the values of $B_{2001}$ and $B_{2001}/K$. Bounding the prior for $P_{72}$ had a negligible effect on expected quantities (scenarios 15 and 16). As expected, decreasing the bounds for the prior of K (scenario 17) resulted in a much lower mean posterior of K, MSY, and $B_{2001}$, while $B_{2001}/K$ increased considerably.

For Atlantic sharpnose, using the scaled series also decreased the predictions of K, MSY, $B_{2001}$, and $B_{2001}/K$ (scenario 1; Table 27). As for the small coastal aggregate, the SC LL catch rate series had the largest leverage of any of the CPUE series, and eliminating it reduced the predictions of K, MSY, $B_{2001}$, and $B_{2001}/K$ from those obtained in the base-case scenario (Table 27). Using a uniform prior on K (scenario 15) reduced the posterior expected value of K, but increased the expected value of $B_{2001}$, with $B_{2001}/K$ remaining the same as in the base-case scenario. Considerably increasing the prior value of r (scenario 16) reduced the expected value of K, doubled the expected value of MSY, and increased the prediction of $B_{2001}/K$, whereas reducing the prior value of r (scenario 18) reduced the expected value of MSY. Bounding the prior for $P_{72}$ had a negligible effect on expected quantities (scenario 19), and decreasing the bounds for the prior of K (scenario 20) resulted in much lower expectations of K, MSY, and $B_{2001}$, while the expected value of $B_{2001}/K$ increased considerably.

For bonnethead, using the scaled series most notably increased the predictions of K and $B_{2001}$ (scenario 1; Table 28). In this case, the SEAMAP catch rate series had the largest leverage of any of the four CPUE series, and eliminating it greatly affected all expected posterior means, reducing K, MSY, $B_{2001}$, and $B_{2001}/K$ from the values obtained in the base-case scenario (scenario 5). Using a uniform prior on K (scenario 6) or bounding the prior for $P_{72}$ (scenario 10) had a negligible effect on expected quantities. Considerably increasing the prior value of r (scenario 7) reduced the expected value of K and increased the expected value of MSY and $B_{2001}/K$, whereas reducing the prior value of r (scenario 9) most notably reduced the expected values of MSY and $B_{2001}/K$. Decreasing the bounds for the prior of K (scenario 11) resulted in lower expectations of K, MSY, and $B_{2001}$, but the expected value of $B_{2001}/K$ did not vary. Increasing the bounds for the prior of K (scenario 12) did not have any effect on expected quantities.

For blacknose, using the scaled series increased somewhat the predictions of K, MSY, and $B_{2001}$ (scenario 1; Table 29). In this case, the SC LL catch rate series also had the largest leverage of any of the seven CPUE series, and eliminating it greatly affected all expected posterior means, reducing K, MSY, $B_{2001}$, and $B_{2001}/K$ from the values obtained in the base-case scenario (scenario 2). Doubling the prior value of r (scenario 9) doubled the expected value of

MSY, whereas halving the prior value of r (scenario 10) halved the expected value of MSY and increased somewhat the expectation of $B_{2001}/K$. Increasing the bounds for the prior of K (scenarios 11 and 12) had a negligible effect on expected quantities. Assuming zero catches reported in some years to be equal to the mean of the catches reported during 1983-1994 (scenario 13) also had a negligible effect.

For finetooth, using the scaled series almost tripled the predictions of K and MSY, almost quadrupled that of $B_{2001}$, and increased the expectation of $B_{2001}/K$ (scenario 1; Table 30). In this case, the Recreational catch rate series had the largest influence of any of the five CPUE series, and eliminating it greatly affected all expected posterior means, more than doubling K, MSY, and $B_{2001}$, and significantly increasing $B_{2001}/K$ from the values obtained in the base-case scenario (scenario 2). Doubling the prior value of r (scenario 7) doubled the expected value of MSY, whereas halving the prior value of r (scenario 8) halved the expected value of MSY. Increasing the bounds for the prior of K (scenarios 9 and 10) had a negligible effect on expected quantities. Assuming the zero catch reported in 1990 to be equal to the mean of the catches reported during 1986- 1994 (scenario 11) also had a negligible effect.

*Bayesian State-Space LRSG model*

For the small coastal aggregate, using the scaled series decreased the predictions of $B_0$, MSY, the biomass that produces MSY ($B_{MSY}$), $B_{2001,}$ and $B_{2001}/K$ (scenario 1; Table 31). The SC LL catch rate series had a very similar effect to that of scenario 1 and the largest effect of any of the CPUE series (scenario 3; Table 31). As expected, decreasing the bounds for the prior of $B_0$ (scenario 11) resulted in a much lower mean posterior of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$, while $B_{2001}/K$ increased considerably. Decreasing the values in the range of the prior for s (scenario 12) greatly increased the expected value of MSY and increased the expected value of $B_{2001}/K$. Decreasing the values in the range of the prior for z (scenarios 13 and 14) considerably decreased the expected value of MSY and increased the expected value of $B_{MSY}$, but the expected values of $B_0$ and $B_{2001}/K$ varied little. The effect of an increase in the lag time to recruitment ($T_{lag}$) of one year (scenario 15) was almost negligible. Using a NMFS GN PC series as a recruitment index (scenario 16) had very little effect, as did setting the bycatch estimates from the South Atlantic in all missing years equal to the mean of the years for which there were estimates (scenario 17), or assuming no bycatch at all in the South Atlantic for any years (scenario 18).

For Atlantic sharpnose, using the scaled series decreased the predictions of $B_0$, s, MSY, $B_{MSY}$, $B_{2001,}$ and $B_{2001}/K$ (scenario 1; Table 32). As for the small coastal aggregate, the SC LL catch rate series had the largest effect of any of the CPUE series, and eliminating it reduced the predictions of $B_0$, MSY, $B_{MSY}$, $B_{2001}$, and $B_{2001}/K$ from those obtained in the base-case scenario (scenario 3; Table 32). Decreasing the bounds for the prior of $B_0$ (scenario 15) resulted in a much lower mean posterior of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$, while $B_{2001}/K$ increased somewhat, z increased, and s decreased. Decreasing the values in the range of the prior for s (scenario 16) greatly increased the expected value of MSY and increased somewhat the expected value of $B_{2001}/K$. Decreasing the values in the range of the prior for z (scenarios 17 and 18) considerably decreased the expected value of MSY and increased the expected value of $B_{MSY}$, but the expected value of $B_{2001}/K$ and especially of $B_{2001}$ varied very little. As for the small coastal aggregate, the effect of an increase in the lag time to recruitment ($T_{lag}$) of one year (scenario 19) was almost negligible. Using a NMFS GN PC series as a recruitment index (scenario 20) had very little effect. Setting the bycatch estimates from the South Atlantic in all missing years equal to the mean of the years for which there were estimates (scenario 21) also had very little effect, most notably a small increase in predicted MSY, whereas assuming no bycatch at all in the South Atlantic for any years (scenario 22) also resulted in little change, with predicted MSY decreasing by about 10%.

For bonnethead, using the scaled series most notably increased the predictions of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$ (scenario 1; Table 33). As in the SPM model, the SEAMAP catch rate series had the largest leverage of any of the four CPUE series, and eliminating it greatly affected all expected posterior means, reducing $B_0$, s, MSY, $B_{MSY}$, $B_{2001}$, and $B_{2001}$/K, and increasing z, with respect to those obtained in the base-case scenario (scenario 5; Table 33). Decreasing the bounds for the prior of $B_0$ (scenario 6) had little effect. Decreasing the values in the range of the prior for s (scenario 7) most notably increased the expected value of MSY and increased somewhat the expected value of $B_{2001}$ and $B_{2001}$/K. Decreasing the values in the range of the prior for z (scenarios 8 and 9) considerably decreased the expected value of MSY and increased the expected value of $B_{MSY}$, but the expected value of $B_{2001}$ and $B_{2001}$/K varied very little. As the for the small coastal aggregate and Atlantic sharpnose, the effect of an increase in the lag time to recruitment ($T_{lag}$) of one year (scenario 10) was small. Setting the bycatch estimates from the South Atlantic in all missing years equal to the mean of the years for which there were estimates (scenario 11) and assuming no bycatch at all in the South Atlantic for any years (scenario 12) both had very little effect on estimated quantities.

For blacknose, using the scaled series did not greatly affect any of the estimated quantities (scenario 1; Table 34). As in the SPM model, the SC LL catch rate series had the largest leverage of any of the seven CPUE series, and eliminating it greatly affected all expected posterior means, reducing $B_0$, MSY, $B_{MSY}$, $B_{2001}$, and $B_{2001}$/K with respect to those obtained in the base-case scenario (scenario 2; Table 34). Increasing the upper bound for the prior of $B_0$ to 40 and 60 million lb dw (scenarios 9 and 10, respectively) had the same identical small effect. Decreasing the values in the range of the prior for s (scenario 11) most notably doubled the expected value of MSY and $B_{MSY}$. Decreasing the values in the range of the prior for z (scenarios 12 and 13) considerably decreased the expected value of MSY and increased the expected value of $B_{MSY}$, but the expected values of $B_{2001}$ and $B_{2001}$/K varied very little. As for the other species analyzed, the effect of an increase in the lag time to recruitment ($T_{lag}$) of one year (scenario 14) was almost negligible. Assuming zero catches reported in some years to be equal to the mean of the catches reported during 1983-1994 (scenario 15) also had a negligible effect on estimated quantities.

For finetooth, using the scaled series had a very profound effect on the predictions of $B_0$, MSY, $B_{MSY}$, $B_{2001}$, and $B_{2001}$/K, increasing them by several factors (scenario 1; Table 35). In this case, both the Recreational and the DGNOP catch rate series had a large influence on estimated management quantities (scenarios 2 and 6). Increasing the upper bound for the prior of $B_0$ to 40 and 60 million lb dw (scenarios 7 and 8, respectively) had the same identical, relatively small effect on estimated management quantities. Decreasing the values in the range of the prior for s (scenario 9) decreased the expected values of $B_0$, $B_{MSY}$, and $B_{2001}$, and increased that of MSY. Decreasing the values in the range of the prior for z (scenarios 10 and 11) considerably decreased the expected value of MSY and increased the expected value of $B_{MSY}$, but the expected values of $B_{2001}$ and $B_{2001}/K$ varied little or not at all, respectively. Increasing the lag time to recruitment ($T_{lag}$) by one year (scenario 12) had an almost negligible effect. Assuming zero catch reported in 1990 to be equal to the mean of the catches reported during 1986-1994 (scenario 13) had a small effect on estimated quantities.

*Convergence diagnostics*

For the base-case scenario of the Bayesian state-space SPM for the small coastal aggregate, the initial run using 100,000 iterations showed that parameter autocorrelations for each chain usually started high but quickly decreased after a lag of 50 iterations only, suggesting that convergence to the posterior was not slow. Cross-correlation matrices showed that some parameters had fairly high correlations, as expected, but in general most correlations between parameters were fairly low, thus not providing strong evidence for slow convergence to the posterior distribution. The Brooks, Gelman and Rubin diagnostic, which examines the two chains combined, had corrected scale reduction factors approximately equal to one, or the 0.975 quantile <1.2, indicating that the samples arose from the stationary distribution, which means that descriptive statistics could be calculated from the combined second half of the iterations from the two chains (Smith 2001). The p values of the Z-score in the Geweke convergence diagnostic were all >0.05 for chain 1, but some p values for chain 2 were <0.05. P values less than 0.05 indicate that there is evidence against convergence. The Heidelberger and Welch halfwidth and stationarity tests indicated that all parameters in both chains had passed both tests, except for $B_{2001}/K$ in chain 1, which failed the stationarity test. In general, results from these two tests suggest that the number of iterations for the MCMC sampler was sufficient for convergence. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This diagnostic also indicated that the number of iterations needed for each parameter was sufficient, with the exception of K in both chains and MSY in chain 1 only. The burn-in period was sufficient for all parameters, but the dependence factors were >5, providing evidence against convergence, and consequently a higher thinning rate was advised.

Based on the above results, several thinning rates (where the samples from every ith iteration are stored) were investigated. A run of 100,000 iterations with a thinning rate of 2 decreased the autocorrelations after a lag of 50 even further but only slightly decreased the correlations between parameters. There still remained some p values <0.05 for the Z-scores of the Geweke test, but all parameters for both chains passed the Brooks, Gelman and Rubin convergence diagnostic and also the Heidelberger and Welch halfwidth and stationarity tests. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient, as was the number of iterations and burn-in period needed for each parameter. The dependence factors were still >5, but significantly reduced with respect to those in the run with a thinning rate of 1. Consequently, higher thinning rates were recommended.

A final run of 100,000 iterations with a thinning rate of 5 was also tested. This run decreased the autocorrelations even further but had a mixed effect on the correlations between parameters, slightly decreasing some but increasing others with respect to those obtained when using the thinning rate of 2. All p values for the Z-scores of the Geweke test were now > 0.05, indicating no evidence against convergence, and all parameters for both chains continued to pass the Brooks, Gelman and Rubin convergence diagnostic and the Heidelberger and Welch halfwidth and stationarity tests. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the default 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient, as was the number of iterations and burn-in period needed for each parameter. The dependence factors continued to decrease and approach the limit of 5 (some were below), but still higher thinning rates were recommended.

Convergence diagnostics is an area of active research (Meyer and Millar 1999a). The limited tests undertaken here showed that in general increasing the thinning rate improved convergence. Spiegelhalter et al. (2000) indicated that the main advantage of increasing the thinning rate is to reduce autocorrelations. Convergence diagnostics on the default runs with 100,000 iterations and a thinning rate of 1 for the small coastal shark aggregate provided somewhat conflicting results. However, results obtained with 100,000 runs and different thinning rates were virtually identical, yet computing time (on a Pentium II PC at 450 MHz) increased considerably (to almost 3 hours) when the thinning rate was increased to 5. Based on the above considerations, runs of 100,000 iterations and a thinning rate of 1 were kept for all base-case analyses, in which the main parameters from each model were examined.

Convergence of the Bayesian state-space LRSG was appreciably better than that of the Bayesian state-space SPM for the small coastal aggregate. Parameter autocorrelations for each chain were substantially lower. Correlations between some pairs of parameters were high, which was to be expected, since some parameters are a function of other parameters in the model. Corrected scale reduction factors from the Brooks, Gelman and Rubin diagnostic were closer to one, p values of the Z-score in the Geweke convergence diagnostic were all >0.05 for chain 1, and only p values for $B_{2001}$ and $B_0$ were <0.05 (0.03) for chain 2. All parameters from both chains passed the Heidelberger and Welch halfwidth and stationarity tests. The Raftery and Lewis convergence diagnostic indicated that the number of iterations needed to estimate the 2.5th quantile with an accuracy of 0.005 and a probability of 0.95 was sufficient. This test also showed that the number of iterations needed for each parameter was sufficient, with the exception of $B_{2001}$ in both chains and $B_0$ in chain 2 only, the burn-in period was sufficient for all parameters, and only the dependence factors for $B_{2001}$ and $B_0$ were substantially higher than 5 for both chains.

Convergence diagnostics for the models applied to the individual species yielded mixed results. Diagnostics of the SPM for Atlantic sharpnose suggested better performance than those of the SPM for the small coastal aggregate. Parameter autocorrelations tended to be lower and all diagnostics, except for Raftery and Lewis, provided less evidence against convergence than found for the small coastal aggregate. Diagnostics of the LRSG for Atlantic sharpnose indicated, however, that convergence was somewhat worse than that achieved with the SPM for that species, with all diagnostics making equal or worse predictions, except for the Raftery and Lewis diagnostic. For the SPM for bonnethead, while autocorrelations and cross-correlations tended to be higher, the other four diagnostics tended to support better convergence than achieved for the small coastal aggregate. As for Atlantic sharpnose, convergence of the LRSG for bonnethead was worse in general terms than that of the SPM. In contrast, diagnostics for the SPM of both blacknose and finetooth tended to support worse convergence than that of the SPM for the small coastal aggregate, Atlantic sharpnose, and bonnethead. As for the other two species, convergence of the LRSG for blacknose and finetooth was worse than that of their respective SPM.

**General discussion**

Results for the blacknose and finetooth sharks were directly influenced by the catch series used, which did not include any bycatch estimates, which in turn influenced the priors chosen for K. This explains the low values of MSY predicted for these two species, especially those obtained through the SPM models. Findings for these two species should be regarded more cautiously than those for the small coastal aggregate, Atlantic sharpnose, and bonnethead, especially because the catch series were also shorter and zero catches were reported in some years. For the Bayesian analyses using the MCMC sampler, this was supported by the convergence diagnostics, which indicated worse convergence of the chains to their target distributions for these two species.

The prior chosen for the steepness parameter, z, was intentionally given an uninformative uniform distribution with wide range (0.2-0.9). In sharks, recruitment is more directly related to spawning stock, and lower values of z than those typically used for assessments of teleost fishes may seem appropriate. Myers et al. (1995) reported a value of z=0.37 for porbeagle (*Lamna nasus*) in a meta-analysis of spawner-recruit relationships for many fish populations, and Simpfendorfer et al. (2000) found values of z <0.6 in a stock assessment of the whiskery shark (*Furgaleus macki*) in southwestern Australia. The prior chosen for z in the present assessment was intended to reflect possible density-dependent mechanisms and influx into the stocks. This argument is analogous to using higher values of the intrinsic rate of increase (r) in surplus production models than those thought to be more likely, based on life history considerations. Note that z could also be calculated from life history parameters dealing with reproduction and natural mortality or re-parameterized as a function of the initial slope of the Beverton-Holt stock-recruitment curve, which can also be calculated from life history information (P. Kleiber, pers. comm., NOAA Fisheries, Honolulu Laboratory, HI).

In conclusion, while results for blacknose and finetooth sharks are more uncertain due to shorter catch and CPUE series, lack of bycatch estimates, and no catches reported in some years, results from the present assessment suggest that stocks of small coastal sharks in waters off the eastern coast of the U.S. are currently (in year 2000) estimated to be at biomass levels at or above those which could produce MSY, and are thus not considered overfished. Current mean and median estimates of fishing mortality rates are generally at or below those that could result in MSY in the long-run, except for finetooth and possibly blacknose sharks. In the case of finetooth sharks, model estimates of recent F levels are above $F_{MSY}$, indicating that recent levels of effort directed at this species, if continued, could result in an overfished status in the relatively near future. The various stock assessment models used and sensitivity analyses run support these general conclusions. Future work should continue to monitor closely the status of the individual species, especially the blacknose and finetooth sharks.

**Acknowledgements**

I thank G. Scott and C. Porch for helpful comments and advice on an earlier version of this manuscript. I thank J. Carlson for providing the NMFS GN PC, LL PC, and DGNOP catch rate series, T. Henwood and M. Grace for the Oregon II, NMFS LL SE ATL, SE EGM, and WGM series, and L. Natanson for the NMFS LL NE series. Thanks are also due to the following individuals for making their datasets available: J. Musick and C. Conrath for the VIMS LL dataset, G. Ulrich for SC LL, J. Boylan and E. Wenner for SEAMAP, and J. Galbraith for NEFSC Bottom Trawl. I also thank S. Nichols for providing the bycatch estimates from the Gulf of Mexico, D. Vaughan, J. Nance and E. Scott-Denton for providing data to estimate bycatch in the South Atlantic, J. Bennet and J. Poffenberger for commercial fishery statistics, B. Slater and P. Phares for recreational survey statistics, and G. Burgess, for average size data from the bottom longline observer program. I finally thank P. Kleiber for providing feedback on the steepness parameter and J. Neer for help with some illustrations.

**REFERENCES**

ASMFC (Atlantic States Marine Fisheries Commission). 2000. SEAMAP-SA 10-year Trawl Report. Results of trawling efforts in the coastal habitat of the South Atlantic Bight, FY 1990-1999. South Carolina Dept. of Nat. Res., Charleston, SC 29422-2559.

Berger, J. O. 1985. Statistical decision theory and Bayesian analysis. 2nd. Ed. Springer-Verlag, New York.

Best, N. G., M. K. Cowles, and S. K. Vines. 1995. CODA manual version 0.30. Medical Research Council Biostatistics Unit, Institute of Public Health, Cambridge, England.

Carlson, J. K. 2001a. A fishery-independent assessment of shark stock abundance for small coastal species in the northeast Gulf of Mexico. Draft Working Document presented at the 2001 Stakeholders Meeting for assessment of small coastal sharks, Mote Marine Laboratory, Sarasota, FL, May 8-9th, 2001.

Carlson, J. K. 2001b. The directed shark drift gillnet fishery: characterization of the small coastal shark catch and a preliminary standardization of catch rates. Draft Working Document presented at the 2001 Stakeholders Meeting for assessment of small coastal sharks, Mote Marine Laboratory, Sarasota, FL, May 8-9th, 2001.

Carlson, J. K. 2001c. A summary of the biological parameters for small coastal shark species from the US south Atlantic and Gulf of Mexico waters. Draft Working Document presented at the 2001 Stakeholders Meeting for assessment of small coastal sharks, Mote Marine Laboratory, Sarasota, FL, May 8-9th, 2001.

Chen S. B., and S. Watanabe. 1989. Age dependence of natural mortality coefficient in fish population dynamics. Nippon Suisan Gakkaishi 55:205-208.

Cortés, E. 1998. Demographic analysis as an aid in shark stock assessment. Fish. Res. 39:199-208.

Cortés, E. 2000a. 2000 Shark Evaluation Annual Report. 23 pp.

Cortés, E. 2000b. Life-history patterns and correlations in sharks. Rev. Fish. Sci. 8:299-344.

Cortés, E. In press. Incorporating uncertainty into demographic modeling: application to shark populations and their conservation. Cons. Biol.

Deriso, R. B. 1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci. 37:268-282.
Gelman, A. and D. B. Rubin. 1992. Inference from iterative simulation using multiple sequences. Stat. Sci. 7:457-511.
Geweke, J. 1992. Evaluating the accuracy of sampling-based approaches to calculating posterior moments. *In*: Bayesian Statistics 4. J. M. Bernardo, J. O. Berger, A. P. Dawid, and A. F. M. Smith (eds.). Clarendon Press, Oxford, U.K.
Gilks, W. R., S. Richardson, and D. J. Spiegelhalter. 1996. Markov chain Monte Carlo in practice. Chapman and Hall, London, U.K.
Heidelberg, P. and P. Welch. 1093. Simulation run length control in the presence of an initial transient. Oper. Res. 31:1109-1144.
Hillborn, R. and M. Mangel. 1997. The Ecological Detective. Princeton University Press, Princeton, New Jersey.
Hood, G. 2000. PopTools version 2.0. Released August 2000. Pest Animal Control Co-operative Research Center, CSIRO, Canberra, Australia.
Jensen, A. L. 1996. Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Can. J. Fish. Aquat. Sci. 53:820-822.
McAllister, M. K. and G. P. Kirkwood. 1998. Bayesian stock assessment: a review and example application using the logistic model. ICES J. Mar. Sci. 55:1031-1060.
McAllister, M. K., E. K. Pikitch, and E. A. Babcock. 2001. Using demographic methods to construct Bayesian priors for the intrinsic rate of increase in the Schaefer model and implications for stock rebuilding. Can. J. Fish. Aquat. Sci. 58:1871-1890.
Meyer, R. and R. B. Millar. 1999a. BUGS in Bayesian stock assessments. Can. J. Fish. Aquat. Sci. 56:1078-1086.
Meyer, R. and R. B. Millar. 1999b. Bayesian stock assessment using a state-space implementation of the delay difference model. Can. J. Fish. Aquat. Sci. 56:37-52.
Millar, R. B. and R. Meyer. 1999. Nonlinear state-space modeling of fisheries biomass dynamics using Metropolis-Hastings within Gibbs sampling. Tech. Rep. STAT9901. Department of Statistics, University of Auckland, Auckland, New Zealand.
Myers, R. A., J. Bridson, and N. J. Barrowman. 1995. Summary of worldwide stock and recruitment data. Can. Tech. Rep. Fish. Aquat. Sci. 2024.
NMFS (National Marine Fisheries Service). 1993. Fishery Management Plan for Sharks of the Atlantic Ocean. NOAA/NMFS, U.S. Dept. of Commerce.
NMFS (National Marine Fisheries Service). 1998. 1998 Report of the Shark Evaluation Workshop. 109pp.
NMFS (National Marine Fisheries Service). 1999. Final Fishery Management Plan for Atlantic Tunas, Swordfish and Sharks. Highly Migratory Species Management Division, Office of Sustainable Fisheries, NMFS, Silver Spring, Maryland.
Parrack, M. L. 1990. A preliminary study of shark exploitation during 1986-1989 in the U.S. FCZ. Contribution MIA-90-493. NMFS, SEFSC, 75 Virginia Beach Drive, Miami, FL 33149. 23pp.
Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39:175-192.
Peterson, I. and J. S. Wroblewski. 1984. Mortality rate of fishes in the pelagic ecosystem. Can. J. Fish. Aquat. Sci. 41:1117-1120.

Raftery, A. L. and S. Lewis. 1992a. Comment: one long run with diagnostics: implementation strategies for Markov chain Monte Carlo. Stat. Sci. 7:493-497.
Raftery, A. L. and S. Lewis. 1992b. How many iterations in the Gibbs sampler? p. 763-774 *In*: Bayesian Statistics 4. J. M. Bernardo, J. O. Berger, A. P. Dawid, and A. F. M. Smith (eds.). Clarendon Press, Oxford, U.K.
Restrepo, V. R. and 10 other authors. 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Tech. Mem. NMFS-F/SPO, U.S. Dept. of Commerce. 54pp.
SAS Institute Inc. 1999. SAS/STAT User's Guide, version 8. Carey, NC: SAS Institute Inc., 1999. 3884pp.
SB-III-5. Scott, G. P., P. J. Phares, and B. Slater. 1996. Recreational catch, average size and effort information for sharks in US Atlantic and Gulf of Mexico waters. Miami Lab. Contrib. ML-95/96-44.
SB-III-9. Ulrich, G. F. 1996. Fishery independent monitoring of large coastal sharks in South Carolina (1993-1995).
Simpfendorfer, C. A., K, Donohue, and N. G. Hall. 2000. Stock assessment and risk analysis for the whiskery shark (*Furgaleus macki* (Whitley)) in south-western Australia. Fish. Res. 47:1-17.
Smith, B. J. 2001. Bayesian output analysis program (BOA) version 0.5.1 user manual. Department of Biostatistics, University of Iowa College of Public Health, Iowa, USA.
Smith, S. E., D. W. Au, and C. Show. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. Mar. Freshwater Res. 49:663-678.
Spiegelhalter D., A. Thomas, and N. Best. 2000. WinBUGS version 1.3. User Manual. April 2000.
Vaughan, D.S., and J.M. Nance. 1998. Estimates of bycatch of mackerel and cobia in U.S. south Atlantic shrimp trawls. Report to Gulf of Mexico and South Atlantic Fishery Management Councils, 25 pp.

**Table 1.** Estimates (in thousands of individuals and pounds dressed weight) of total landings for small coastal sharks.

| Year | Col 1 Commercial (lb dw) | Col 2 Av. Wt (lb dw) | Col 3 Mt landed/ Av. wt | Col 4 Rec. Catches (numbers) | Col 5 Rec. Catches (lb dw) | Col 6 Total (numbers) | Col 7 Total (lb dw) |
|---|---|---|---|---|---|---|---|
| 1995 | 538.5 | 3.858 | 139.6 | 170.7 | 431.1 | 310.3 | 969.6 |
| 1996 | 484.8 | 4.094 | 118.4 | 113.5 | 241.3 | 231.9 | 726.1 |
| 1997 | 704.9 | 3.291 | 214.2 | 98.5 | 259.9 | 312.7 | 964.8 |
| 1998 | 631.9 | 3.362 | 187.9 | 169.8 | 508.3 | 357.7 | 1,140.2 |
| 1999 | 727.3 | 3.267 | 222.6 | 111.5 | 280.3 | 334.1 | 1,007.6 |
| 2000 | 577.2 | 3.518 | 164.1 | 187.1 | 434.7 | 351.2 | 1,011.9 |

Column 1, commercial landings in lb dw - These data are the landings reported under the established NMFS Cooperative statistics program. (see document SB-III-6 for a description of this data collection program.) The data are collected in landed or dressed weight. Values updated from SB-IV-12, Table 2 in Cortés (1999, 2000) and Table 2 herein.

Column 2, average weights in lb dw - The data for this column are predicted weights from lengths based on the directed shark fishery observer program (Branstetter and Burgess 1997; G. Burgess, U. of Florida, pers. comm.)

Column 3, number of sharks caught and landed commercially (in thousands) - Data in this column are calculated as the ratio of column 1 (mt landed) and column 2 (average weight in lb dw).

Column 4, recreational harvest – Estimated catches in numbers (in thousands) updated from the NMFS MRFSS, Headboat and charter boat surveys and the Texas Parks and Wildlife (TPWD) recreational creel survey. The estimate for 2000 is based on catches reported from MRFSS and assuming that catches from the Headboat and TPWD surveys were the same as those reported for 1999 since catches from these two sources were not yet available for 2000.

Column 5, recreational harvest – Estimated catches in lb dw (in thousands) – Data in this column were obtained by multiplying the catch in numbers reported in each of the three recreational surveys (whose sum is given in column 4) by the average weights from these surveys reported in Table 4.

Column 6, total in numbers - The numbers in this column are the sum of columns 3 and 4.

Column 7, total in dressed weight - The numbers in this column are the sum of columns 1 and 5.

**Table 2.** Estimates of total landings for Atlantic sharpnose, blacknose, bonnethead, and finetooth sharks.

| Year | Col 1 Commercial (lb landed) | Col 2 Av. Wt (lb dw) | Col 3 Mt landed/ Av. wt | Col 4 Rec. Catches (numbers) | Col 5 Rec. Catches (lb dw) | Col 6 Total (numbers) | Col 7 Total (lb dw) |
|---|---|---|---|---|---|---|---|
| **Atlantic sharpnose** | | | | | | | |
| 1995 | 93,663 | 3.41 | 27,437 | 133,406 | 368,213 | 160,843 | 461,876 |
| 1996 | 165,406 | 3.37 | 49,113 | 73,626 | 182,955 | 122,739 | 348,361 |
| 1997 | 256,562 | 3.26 | 78,777 | 67,726 | 192,056 | 146,503 | 448,618 |
| 1998 | 230,920 | 3.16 | 72,977 | 129,315 | 442,887 | 202,292 | 673,807 |
| 1999 | 244,356 | 3.18 | 76,808 | 68,718 | 195,768 | 145,526 | 440,124 |
| 2000 | 129,467 | 3.50 | 37,031 | 122,422 | 305,565 | 159,453 | 435,032 |
| **Blacknose** | | | | | | | |
| 1995 | 96,487 | 6.16 | 15,672 | 2,890 | 8,664 | 18,562 | 105,151 |
| 1996 | 144,433 | 6.02 | 23,981 | 11,831 | 15,192 | 35,812 | 159,625 |
| 1997 | 202,781 | 4.63 | 43,792 | 10,705 | 19,050 | 54,497 | 221,831 |
| 1998 | 119,689 | 5.13 | 23,345 | 10,523 | 23,207 | 33,868 | 142,896 |
| 1999 | 137,619 | 4.74 | 29,057 | 6,019 | 5,343 | 35,076 | 142,962 |
| 2000 | 176,394 | 3.82 | 46,161 | 9,477 | 14,329 | 55,638 | 190,723 |
| **Bonnethead** | | | | | | | |
| 1995 | 295,026 | 4.28 | 68,964 | 32,318 | 42,382 | 101,282 | 337,408 |
| 1996 | 78,638 | 6.15 | 12,796 | 22,142 | 32,887 | 34,938 | 111,525 |
| 1997 | 75,787 | 4.81 | 15,752 | 15,307 | 31,794 | 31,059 | 107,581 |
| 1998 | 13,949 | 5.26 | 2,650 | 29,692 | 50,812 | 32,342 | 64,761 |
| 1999 | 58,150 | 5.07 | 11,471 | 36,703 | 73,878 | 48,174 | 132,028 |
| 2000 | 69,258 | 5.07 | 13,662 | 53,295 | 86,167 | 66,957 | 155,425 |

**Table 2.** (continued).

| Finetooth | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1995 | 50,193 | 14.31 | 3,508 | 1,203 | 4,519 | 4,711 | 54,712 |
| 1996 | 94,134 | 11.42 | 8,240 | 1,605 | 2,326 | 9,845 | 96,460 |
| 1997 | 169,733 | 11.42 | 14,857 | 4,763 | 12,103 | 19,620 | 181,836 |
| 1998 | 267,224 | 11.42 | 23,390 | 139 | 827 | 23,529 | 268,051 |
| 1999 | 285,214 | 11.42 | 24,965 | 78 | 281 | 25,043 | 285,495 |
| 2000 | 190,313 | 11.42 | 16,658 | 1,201 | 4,392 | 17,859 | 194,705 |

Column 1, commercial landings in lb dw- These data are the landings reported under the established NMFS cooperative statistics program. (See document SB-III-6 for a description of this data collection program.) The data are collected in landed or dressed weight. Values updated from SB-IV-12, Table 2 in Cortés (1999, 2000) and Table 2 herein.

Column 2, average weights in lb dw - The data for this column are predicted weights from lengths based on the directed shark fishery observer program (Branstetter and Burgess 1997; G. Burgess, U. of Florida, pers. comm.). For the finetooth shark, average weights were not available for 1997-2000 and the value for 1996 was assumed for those years; for the bonnethead, an average weight was not available for 2000 and the value for 1999 was assumed for that year.

Column 3, number of sharks caught and landed commercially - Data in this column are calculated as the ratio of column 1 (lb landed) and column 2 (average weight in lb dw).

Column 4, recreational harvest – Estimated catches in numbers updated from the NMFS MRFSS, Headboat and charter boat surveys and the Texas Parks and Wildlife (TPWD) recreational creel survey. The estimate for 2000 is based on catches reported from MRFSS and assuming that catches from the Headboat and TPWD surveys were the same as those reported for 1999 since catches from these two sources were not yet available for 2000.

Column 5, recreational harvest – Estimated catches in lb dw – Data in this column were obtained by multiplying the catch in numbers reported in each of the three recreational surveys (whose sum is given in column 4) by the average weights from these surveys reported in Tables 5-8.

Column 6, total in numbers - The numbers in this column are the sum of columns 3 and 4.

Column 7, total in dressed weight - The numbers in this column are the sum of columns 1 and 5.

**Table 3.** Estimates of total annual recreational catches in numbers of small coastal sharks (as a complex and by species) and of total annual effort (measured as angler days) estimated from MRFSS, HBOAT, and TXPWD.

| Year | All SCS | Atlantic sharpnose | Blacknose | Bonnethead | Finetooth | Effort |
|---|---|---|---|---|---|---|
| 1981 | 82,759 | 43,490 | | 39,269 | | 43,494,044 |
| 1982 | 67,647 | 40,656 | | 26,115 | | 52,384,610 |
| 1983 | 81,839 | 45,208 | 13,936 | 22,695 | | 64,190,589 |
| 1984 | 51,828 | 34,781 | 844 | 14,317 | | 57,875,519 |
| 1985 | 40,304 | 17,829 | 1,918 | 20,557 | | 56,464,096 |
| 1986 | 103,833 | 34,923 | 3,308 | 53,386 | 11,819 | 61,694,805 |
| 1987 | 105,899 | 48,750 | 15,382 | 31,521 | 17 | 55,178,341 |
| 1988 | 156,835 | 82,375 | 15,971 | 35,650 | 22,839 | 60,688,085 |
| 1989 | 106,064 | 62,332 | 1,793 | 41,782 | 157 | 50,808,151 |
| 1990 | 99,990 | 47,283 | 3,345 | 49,308 | 54 | 47,143,256 |
| 1991 | 150,132 | 137,018 | 8 | 12,595 | 511 | 59,640,302 |
| 1992 | 163,202 | 116,162 | 5,199 | 32,498 | 9,321 | 54,244,385 |
| 1993 | 128,851 | 78,679 | 3,024 | 28,648 | 18,500 | 57,257,462 |
| 1994 | 143,186 | 103,194 | 14,464 | 21,573 | 3,347 | 61,456,295 |
| 1995 | 170,744 | 133,406 | 2,890 | 32,318 | 1,203 | 59,952,066 |
| 1996 | 113,493 | 73,626 | 11,831 | 22,142 | 1,605 | 58,215,367 |
| 1997 | 98,501 | 67,726 | 10,705 | 15,307 | 4,763 | 63,159,477 |
| 1998 | 169,779 | 129,315 | 10,523 | 29,692 | 139 | 56,250,521 |
| 1999 | 111,522 | 68,718 | 6,019 | 36,703 | 78 | |
| 2000 | 187,058 | 122,422 | 9,477 | 53,295 | 1,201 | |

**Table 4.** Average weights (lb dw) of the **SCS complex** predicted from lengths recorded in the bottom-longline observer program (BLLOP), Trip Interview Program (TIP), and MRFSS, HBOAT, and TXPWD surveys. Standard errors of the mean (SE) and sample size (n) are indicated. Data for sample sizes <10 are in italics.

| | BLLOP | | | TIP | | | MRFSS | | | HBOAT | | | TXPWD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n |
| 1981 | | | | | | | 1.68 | 0.17 | 18 | | | | | | |
| 1982 | | | | | | | 1.83 | 0.33 | 36 | | | | | | |
| 1983 | | | | | | | 1.67 | 0.57 | 14 | | | | 2.85 | 0.14 | 157 |
| 1984 | | | | *2.34* | *0.22* | *3* | 1.49 | 0.56 | 16 | *3.36* | *0.69* | *2* | 3.14 | 0.11 | 261 |
| 1985 | | | | *5.34* | *0.27* | *4* | 1.87 | 0.23 | 19 | | | | 3.20 | 0.09 | 323 |
| 1986 | | | | *4.23* | *0.16* | *6* | 1.96 | 0.13 | 68 | 3.94 | 0.08 | 251 | 2.98 | 0.11 | 223 |
| 1987 | | | | *3.93* | *0.38* | *5* | 2.11 | 0.13 | 53 | 4.71 | 0.03 | 759 | 2.29 | 0.10 | 312 |
| 1988 | | | | | | | 2.17 | 0.11 | 83 | 4.60 | 0.02 | 1031 | 2.85 | 0.08 | 425 |
| 1989 | | | | | | | 1.99 | 0.25 | 31 | 4.61 | 0.04 | 612 | 2.28 | 0.10 | 271 |
| 1990 | | | | 3.46 | 0.05 | 356 | 1.98 | 0.14 | 44 | 4.51 | 0.06 | 468 | 2.32 | 0.10 | 203 |
| 1991 | | | | 3.41 | 0.07 | 216 | 1.91 | 0.10 | 66 | 4.01 | 0.07 | 259 | 2.37 | 0.12 | 149 |
| 1992 | | | | 3.92 | 0.13 | 56 | 2.01 | 0.06 | 220 | 3.36 | 0.05 | 603 | 3.03 | 0.16 | 176 |
| 1993 | 3.43 | 0.08 | 16 | 3.52 | 0.04 | 301 | 1.90 | 0.10 | 74 | 3.61 | 0.05 | 521 | 2.95 | 0.16 | 102 |
| 1994 | 4.58 | 0.13 | 242 | 2.34 | 0.18 | 106 | 2.49 | 0.16 | 128 | 3.78 | 0.05 | 512 | 2.68 | 0.13 | 165 |
| 1995 | 3.86 | 0.03 | 2605 | 1.20 | 0.24 | 81 | 2.32 | 0.14 | 91 | 3.65 | 0.05 | 715 | 3.55 | 0.18 | 120 |
| 1996 | 4.09 | 0.04 | 1674 | | | | 1.70 | 0.10 | 74 | 4.25 | 0.04 | 540 | 3.21 | 0.13 | 160 |
| 1997 | 3.29 | 0.16 | 1589 | | | | 2.23 | 0.14 | 92 | 3.87 | 0.05 | 444 | 3.94 | 0.22 | 161 |
| 1998 | 3.36 | 0.02 | 1996 | *4.96* | *0.04* | *2* | 1.97 | 0.14 | 97 | 3.94 | 0.03 | 903 | 3.84 | 0.14 | 217 |
| 1999 | 3.27 | 0.02 | 2159 | | | | 2.06 | 0.09 | 170 | 3.84 | 0.03 | 837 | 3.65 | 0.16 | 141 |
| 2000 | 3.52 | 0.02 | 698 | | | | 2.05 | 0.05 | 371 | | | | | | |

**Table 5.** Average weights (lb dw) of **Atlantic sharpnose sharks** predicted from lengths recorded in the bottom-longline observer program (BLLOP), Trip Interview Program (TIP), and MRFSS, HBOAT, and TXPWD surveys. Standard errors of the mean (SE) and sample size (n) are indicated. Data for sample sizes <10 are in italics.

| | BLLOP | | | TIP | | | MRFSS | | | HBOAT | | | TXPWD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n |
| 1981 | | | | | | | 2.08 | 0.08 | 13 | | | | | | |
| 1982 | | | | | | | 1.13 | 0.20 | 17 | | | | | | |
| 1983 | | | | | | | *1.57* | *0.39* | *2* | | | | 3.17 | 0.15 | 120 |
| 1984 | | | | *2.34* | *0.22* | *3* | 1.18 | 0.58 | 10 | | | | 3.44 | 0.13 | 197 |
| 1985 | | | | *5.34* | *0.28* | *4* | *2.06* | *0.34* | *6* | | | | 3.58 | 0.10 | 263 |
| 1986 | | | | *4.23* | *0.16* | *6* | 2.17 | 0.13 | 35 | 3.90 | 0.08 | 244 | 3.28 | 0.13 | 167 |
| 1987 | | | | *3.93* | *0.38* | *5* | 2.26 | 0.13 | 42 | 4.69 | 0.03 | 753 | 2.34 | 0.11 | 234 |
| 1988 | | | | | | | 2.23 | 0.10 | 59 | 4.60 | 0.02 | 1031 | 3.30 | 0.08 | 286 |
| 1989 | | | | | | | 1.84 | 0.27 | 25 | 4.72 | 0.03 | 578 | 2.40 | 0.13 | 194 |
| 1990 | | | | 3.47 | 0.06 | 342 | 1.87 | 0.13 | 19 | 4.47 | 0.05 | 464 | 2.22 | 0.11 | 144 |
| 1991 | | | | 3.42 | 0.07 | 210 | 1.91 | 0.09 | 62 | 4.02 | 0.07 | 254 | 2.43 | 0.18 | 84 |
| 1992 | | | | 3.80 | 0.11 | 52 | 1.97 | 0.07 | 167 | 3.32 | 0.05 | 588 | 3.50 | 0.14 | 133 |
| 1993 | 3.43 | 0.08 | 16 | 3.51 | 0.04 | 290 | 1.86 | 0.13 | 44 | 3.58 | 0.05 | 508 | 3.65 | 0.20 | 64 |
| 1994 | 2.95 | 0.07 | 109 | 2.71 | 0.26 | 43 | 2.26 | 0.08 | 91 | 3.78 | 0.05 | 504 | 2.84 | 0.17 | 109 |
| 1995 | 3.41 | 0.01 | 2184 | | | | 2.56 | 0.14 | 62 | 3.64 | 0.05 | 703 | 3.81 | 0.17 | 72 |
| 1996 | 3.37 | 0.01 | 1224 | | | | 1.93 | 0.10 | 46 | 4.26 | 0.04 | 537 | 3.54 | 0.14 | 112 |
| 1997 | 3.26 | 0.01 | 1550 | | | | 2.34 | 0.16 | 65 | 3.83 | 0.05 | 437 | 3.81 | 0.13 | 119 |
| 1998 | 3.16 | 0.02 | 1795 | | | | 2.08 | 0.15 | 59 | 3.95 | 0.03 | 899 | 4.11 | 0.11 | 160 |
| 1999 | 3.18 | 0.01 | 2040 | | | | 2.15 | 0.08 | 130 | 3.85 | 0.03 | 835 | 3.77 | 0.16 | 96 |
| 2000 | 3.50 | 0.01 | 650 | | | | 2.09 | 0.04 | 307 | | | | | | |

**Table 6.** Average weights (lb dw) of **blacknose sharks** predicted from lengths recorded in the bottom-longline observer program (BLLOP), Trip Interview Program (TIP), and MRFSS, HBOAT, and TXPWD surveys. Standard errors of the mean (SE) and sample size (n) are indicated. Data for sample sizes <10 are in italics.

| | BLLOP | | | TIP | | | MRFSS | | | HBOAT | | | TXPWD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | N | Av. wt | SE | n | Av. wt | SE | n |
| 1981 | | | | | | | | | | | | | | | |
| 1982 | | | | | | | | | | | | | | | |
| 1983 | | | | | | | *2.13* | *1.29* | *6* | | | | | | |
| 1984 | | | | | | | | | | | | | | | |
| 1985 | | | | | | | | | | | | | | | |
| 1986 | | | | | | | 1.26 | 0.27 | 11 | *3.89* | *0.14* | *2* | | | |
| 1987 | | | | | | | *0.73* | *0.24* | *4* | | | | | | |
| 1988 | | | | | | | *1.03* | *0.26* | *9* | | | | | | |
| 1989 | | | | | | | | | | 1.32 | 0.13 | 14 | | | |
| 1990 | | | | 3.15 | 0.15 | 13 | | | | | | | | | |
| 1991 | | | | *2.85* | *0.23* | *6* | | | | | | | | | |
| 1992 | | | | | | | *1.64* | *0.33* | *8* | | | | | | |
| 1993 | | | | *3.98* | *0.51* | *8* | *1.64* | *0.31* | *6* | | | | | | |
| 1994 | 5.92 | 0.16 | 132 | | | | 2.77 | 0.52 | 13 | | | | | | |
| 1995 | 6.16 | 0.12 | 406 | 0.92 | 0.05 | 79 | *2.98* | *0.96* | *4* | | | | *5.17* | *1.03* | *2* |
| 1996 | 6.02 | 0.08 | 414 | | | | 1.29 | 0.32 | 10 | | | | | | |
| 1997 | 4.63 | 0.36 | 38 | | | | *1.78* | *0.47* | *8* | | | | | | |
| 1998 | 5.13 | 0.14 | 197 | | | | 2.20 | 0.47 | 11 | *2.29* | *0.51* | *4* | | | |
| 1999 | 4.74 | 0.23 | 116 | | | | 0.90 | 0.25 | 12 | | | | *4.61* | *0.50* | *2* |
| 2000 | 3.82 | 0.13 | 48 | | | | 1.51 | 0.25 | 13 | | | | | | |

**Table 7.** Average weights (lb dw) of **bonnetheads** predicted from lengths recorded in the bottom-longline observer program (BLLOP), Trip Interview Program (TIP), and MRFSS, HBOAT, and TXPWD surveys. Standard errors of the mean (SE) and sample size (n) are indicated. Data for sample sizes <10 are in italics.

| | BLLOP | | | TIP | | | MRFSS | | | HBOAT | | | TXPWD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n |
| 1981 | | | | | | | *0.64* | *0.19* | *5* | | | | | | |
| 1982 | | | | | | | 2.46 | 0.58 | 19 | | | | | | |
| 1983 | | | | | | | *1.24* | *0.47* | *6* | | | | 1.41 | 0.14 | 30 |
| 1984 | | | | | | | *2.29* | *1.41* | *5* | *3.36* | *0.69* | *2* | 2.13 | 0.26 | 41 |
| 1985 | | | | | | | 1.72 | 0.32 | 12 | | | | 1.47 | 0.11 | 55 |
| 1986 | | | | | | | *3.18* | *0.64* | *8* | *3.99* | *0.77* | *3* | 2.01 | 0.19 | 54 |
| 1987 | | | | | | | *1.98* | *0.38* | *7* | *2.36* | *0.16* | *2* | 2.13 | 0.22 | 78 |
| 1988 | | | | | | | *1.66* | *0.60* | *5* | | | | 1.75 | 0.10 | 118 |
| 1989 | | | | | | | *2.63* | *0.63* | *6* | *1.99* | *0.76* | *3* | 2.02 | 0.14 | 72 |
| 1990 | | | | | | | 2.05 | 0.23 | 25 | *6.73* | *2.11* | *3* | 2.60 | 0.21 | 58 |
| 1991 | | | | | | | *1.88* | *0.89* | *4* | *4.25* | *1.64* | *4* | 2.25 | 0.19 | 59 |
| 1992 | | | | *6.09* | *1.21* | *3* | 2.28 | 0.16 | 42 | 4.80 | 0.24 | 14 | 1.12 | 0.09 | 33 |
| 1993 | | | | *4.00* | *0.70* | *3* | 1.95 | 0.32 | 12 | 4.63 | 0.49 | 13 | 1.93 | 0.18 | 22 |
| 1994 | | | | 2.08 | 0.24 | 63 | 2.28 | 0.43 | 16 | *3.29* | *0.15* | *6* | 2.55 | 0.24 | 42 |
| 1995 | 4.28 | 0.66 | 12 | | | | 1.25 | 0.27 | 20 | 4.69 | 0.59 | 11 | 2.02 | 0.20 | 31 |
| 1996 | 6.15 | 0.26 | 33 | | | | 1.39 | 0.32 | 16 | | | | 2.52 | 0.26 | 38 |
| 1997 | | | | | | | *2.04* | *0.62* | *9* | | | | 2.42 | 0.28 | 34 |
| 1998 | *5.26* | *0.93* | *4* | *4.96* | *0.04* | *2* | 1.65 | 0.32 | 27 | | | | 2.78 | 0.39 | 54 |
| 1999 | *5.07* | *1.26* | *3* | | | | 2.01 | 0.35 | 26 | | | | 3.35 | 0.39 | 43 |
| 2000 | | | | | | | 1.62 | 0.18 | 42 | | | | | | |

**Table 8.** Average weights (lb dw) of **finetooth sharks** predicted from lengths recorded in the bottom-longline observer program (BLLOP), Trip Interview Program (TIP), and MRFSS, HBOAT, and TXPWD surveys. Standard errors of the mean (SE) and sample size (n) are indicated. Data for sample sizes <10 are in italics.

| | BLLOP | | | TIP | | | MRFSS | | | HBOAT | | | TXPWD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n | Av. wt | SE | n |
| 1981 | | | | | | | | | | | | | | | |
| 1982 | | | | | | | | | | | | | | | |
| 1983 | | | | | | | | | | | | | *3.62* | *1.20* | *7* |
| 1984 | | | | | | | | | | | | | 2.36 | 0.45 | 23 |
| 1985 | | | | | | | | | | | | | *2.23* | *0.66* | *5* |
| 1986 | | | | | | | 1.29 | 0.20 | 14 | *8.79* | *2.56* | *2* | *4.72* | *2.88* | *2* |
| 1987 | | | | | | | | | | *9.35* | *1.01* | *4* | | | |
| 1988 | | | | | | | 3.05 | 0.53 | 10 | | | | 2.94 | 0.64 | 21 |
| 1989 | | | | | | | | | | 3.84 | 0.63 | 17 | *1.41* | *0.33* | *5* |
| 1990 | | | | | | | | | | | | | | | |
| 1991 | | | | | | | | | | | | | 2.66 | 0.29 | 6 |
| 1992 | | | | | | | *1.58* | *0.72* | *3* | | | | 3.13 | 1.91 | 10 |
| 1993 | | | | | | | 2.09 | 0.24 | 12 | | | | 1.32 | 0.13 | 15 |
| 1994 | | | | | | | *5.02* | *1.89* | *8* | *6.70* | *0.19* | *2* | 1.86 | 0.15 | 14 |
| 1995 | *14.31* | *6.14* | *3* | | | | *3.01* | *0.50* | *5* | | | | 5.26 | 0.75 | 15 |
| 1996 | *11.42* | *4.23* | *3* | | | | *1.16* | *0.12* | *2* | | | | 2.11 | 0.53 | 10 |
| 1997 | | | | | | | 2.02 | 0.19 | 10 | *5.99* | *0.59* | *7* | *12.31* | *2.44* | *8* |
| 1998 | | | | | | | | | | | | | *8.9* | *3.00* | *3* |
| 1999 | | | | | | | *4.08* | *0.13* | *2* | | | | | | |
| 2000 | | | | | | | *3.66* | *0.74* | *9* | | | | | | |

**Table 9.** Expanded estimates of bycatch of bonnethead, Atlantic sharpnose, and finetooth sharks in the U.S. south Atlantic shrimp trawl fishery based on within-stratum expansion by effort as trips by fishing year.

| | | | Bonnethead | | | Atlantic sharpnose | | | Finetooth | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Area | Season | Trips | CPT[1] | CV | Catch | CPT | CV | Catch | CPT | CV | Catch |
| | | | | | **1992-93** | | | | | | |
| FGS | Spring | 4505 | 9.427 | 249.7 | 42471 | 336.148 | 88.8 | 1514348 | 0.00 | - | 0 |
| FGS | Summer | 4439 | 0.003 | 282.8 | 13 | 40.581 | 94.9 | 180140 | 0.00 | - | 0 |
| FGS | Fall | 11237 | 0.996 | 381.9 | 11190 | 5.281 | 279.5 | 59342 | 0.00 | - | 0 |
| NCI | Summer | 9355 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| | Total: | 20181 | | | *53674* | | | *1753829* | | | *0* |
| | | | | | **1993-94** | | | | | | |
| FSO | Spring | 214 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| FSO | Summer | 332 | 0.000 | - | 0 | 19.132 | - | 6352 | 0.000 | - | 0 |
| FGS | Spring | 5039 | 0.000 | - | 0 | 282.855 | 119.5 | 1425307 | 24.960 | 35.3 | 125773 |
| FGS | Summer | 5065 | 0.000 | - | 0 | 874.885 | - | 4431293 | 63.518 | - | 321721 |
| FGS | Winter | 963 | 0.000 | - | 0 | 10.780 | 120.5 | 10381 | 0.000 | - | 0 |
| NCI | Spring | 813 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| NCI | Summer | 8019 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| | Total: | 20445 | | | *0* | | | *5873333* | | | *447495* |
| | | | | | **1995-96** | | | | | | |
| FSO | Summer | 157 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| FGS | Spring | 6229 | 3.750 | 200 | 23359 | 0.000 | - | 0 | 0.000 | - | 0 |
| FGS | Summer | 5212 | 2.114 | 164.3 | 11020 | 0.000 | - | 0 | 0.000 | - | 0 |
| FGS | Fall | 11735 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| | Total: | 23333 | | | *34378* | | | *0* | | | *0* |
| | | | | | **1996-97** | | | | | | |
| FGS | Spring | 3104 | 4.944 | 217.2 | 15347 | 21.758 | 252.997 | 67538 | 0.000 | - | 0 |
| FGS | Summer | 5149 | 4.500 | 141.4 | 23171 | 56.5 | 111.385 | 290919 | 0.000 | - | 0 |
| FGS | Fall | 11067 | 0.000 | - | 0 | 0.000 | - | 0 | 0.000 | - | 0 |
| | Total: | 19320 | | | *38517* | | | *358457* | | | *0* |

[1] CPT: catch per trip

**Table 10.** Length-frequency distributions of bonnethead, Atlantic sharpnose, and finetooth sharks sampled in the U.S. South Atlantic shrimp trawl fishery by fishing year.

| Species | Year | Length interval (cm total length) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 11-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | 81-90 | N |
| Finetooth | 1993 | | | | 1 | 2 | | | | 3 |
| Atlantic sharpnose | 1992 | 5 | 3 | 181 | 8 | | | | | 197 |
| Atlantic sharpnose | 1993 | | 5 | 51 | 12 | 4 | 2 | | | 74 |
| Atlantic sharpnose | 1996 | | 2 | 16 | 5 | | | | 1 | 24 |
| Bonnethead | 1992 | | | 2 | 3 | 1 | | | | 6 |
| Bonnethead | 1995 | | | | 1 | | 3 | | | 4 |
| Bonnethead | 1996 | | | | | 2 | | 1 | 1 | 4 |

**Table 11.** Mean total length (CV in parentheses), weight, and estimated age of bonnethead, Atlantic sharpnose, and finetooth sharks sampled in the U.S. South Atlantic shrimp trawl fishery by fishing year.

| Species | Year | Total length (cm) | Weight (kg) | Age (years) | N |
|---|---|---|---|---|---|
| Finetooth | 1993 | 50.9 (3.3) | 0.667 | 0 | 3 |
| Atlantic sharpnose | 1992 | 34.3 (12.4) | 0.295 | 0 | 197 |
| Atlantic sharpnose | 1993 | 38.3 (18.6) | 0.405 | 0.15 | 74 |
| Atlantic sharpnose | 1996 | 39.8 (27.5) | 0.483 | 0.31 | 24 |
| Bonnethead | 1992 | 42.3 (22.8) | 0.411 | 0.27 | 6 |
| Bonnethead | 1995 | 59.1 (13.0) | 1.083 | 1.04 | 4 |
| Bonnethead | 1996 | 68.3 (19.8) | 1.813 | 1.65 | 4 |

**Table 12.** Estimates (in thousands of individuals and pounds dressed weight) of the bycatch of small coastal sharks (as a complex and by species) in the shrimp trawl fishery operating in the Gulf of Mexico (S. Nichols, NMFS Pascagoula Laboratories, pers. comm.).

| Year | All SCS (numbers) | All SCS (lb dw) | Atlantic sharpnose (numbers) | Atlantic sharpnose (lb dw) | Bonnethead (numbers) | Bonnethead (lb dw) |
|---|---|---|---|---|---|---|
| 1972 | 1,575 | 1,500 | 1,051 | 1,010 | 0,468 | 0,371 |
| 1973 | 1,579 | 1,580 | 0,831 | 0,842 | 0,620 | 0,525 |
| 1974 | 1,903 | 1,899 | 1,508 | 1,407 | 0,420 | 0,400 |
| 1975 | 2,055 | 1,997 | 1,587 | 1,473 | 0,347 | 0,313 |
| 1976 | 2,193 | 2,209 | 1,706 | 1,632 | 0,456 | 0,436 |
| 1977 | 2,187 | 2,142 | 1,507 | 1,457 | 0,520 | 0,427 |
| 1978 | 2,223 | 2,156 | 1,799 | 1,625 | 0,367 | 0,370 |
| 1979 | 2,829 | 2,754 | 2,384 | 2,254 | 0,388 | 0,341 |
| 1980 | 2,591 | 2,436 | 2,148 | 1,933 | 0,368 | 0,330 |
| 1981 | 2,081 | 2,007 | 1,830 | 1,649 | 0,242 | 0,252 |
| 1982 | 2,281 | 2,203 | 1,850 | 1,661 | 0,302 | 0,310 |
| 1983 | 2,138 | 2,193 | 1,856 | 1,821 | 0,255 | 0,250 |
| 1984 | 1,551 | 1,509 | 1,277 | 1,191 | 0,232 | 0,230 |
| 1985 | 1,767 | 1,796 | 1,451 | 1,442 | 0,260 | 0,249 |
| 1986 | 2,222 | 2,234 | 1,464 | 1,519 | 0,624 | 0,506 |
| 1987 | 3,216 | 3,123 | 2,636 | 2,392 | 0,516 | 0,519 |
| 1988 | 2,535 | 2,272 | 1,959 | 1,664 | 0,421 | 0,404 |
| 1989 | 2,116 | 2,216 | 1,632 | 1,713 | 0,336 | 0,286 |
| 1990 | 1,981 | 2,069 | 1,503 | 1,507 | 0,489 | 0,431 |
| 1991 | 2,350 | 2,322 | 1,784 | 1,756 | 0,365 | 0,323 |
| 1992 | 2,759 | 2,879 | 1,968 | 1,997 | 0,494 | 0,459 |
| 1993 | 2,226 | 2,213 | 1,710 | 1,626 | 0,416 | 0,400 |
| 1994 | 2,197 | 2,243 | 1,586 | 1,591 | 0,395 | 0,347 |
| 1995 | 2,401 | 2,362 | 1,806 | 1,636 | 0,311 | 0,299 |
| 1996 | 2,923 | 2,457 | 2,069 | 1,644 | 0,519 | 0,428 |
| 1997 | 2,883 | 2,926 | 1,732 | 1,681 | 0,486 | 0,439 |
| 1998 | 2,657 | 2,410 | 1,662 | 1,494 | 0,376 | 0,329 |
| 1999 | 1,282 | 1,257 | 0,906 | 0,848 | 0,218 | 0,198 |
| 2000 | 1,282 | 1,257 | 0,906 | 0,848 | 0,218 | 0,198 |

**Table 13.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for the **small coastal shark** aggregate in SEAMAP. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**SEAMAP**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 2931 | 4061.07 | 1.3856 | | | -2030.5 | | |
| MONTH | 2924 | 3339.96 | 1.1423 | 17.56 | 17.56 | -1669.98 | 721.10 | <0.0001 |
| AREA | 2908 | 3916.74 | 1.3469 | 2.79 | | -1958.37 | 144.33 | <0.0001 |
| YEAR | 2919 | 3983.51 | 1.3647 | 1.51 | | -1991.76 | 77.55 | <0.0001 |
| **MONTH +** | | | | | | | | |
| AREA | 2901 | 3133.08 | 1.0800 | 22.06 | 4.50 | -1566.54 | 206.88 | <0.0001 |
| YEAR | 2912 | 3272.80 | 1.1239 | 18.89 | | -1636.40 | 67.16 | <0.0001 |
| **MONTH + AREA** | | | | | | | | |
| YEAR | 2889 | 3053.17 | 1.0568 | 23.73 | 1.67 | -1526.59 | 79.90 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor | | |
|---|---|---|---|---|---|---|
| | | | | MONTH | AREA | YEAR |
| **MONTH+AREA+YEAR** | 13912.2 | 13918.1 | 13910.2 | <0.0001 | <0.0001 | <0.0001 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 1363 | 9668.47 | 7.0935 | | | 4672.59 | | |
| MONTH | 1356 | 8256.12 | 6.0886 | 14.17 | 14.17 | 7178.77 | 1412.35 | <0.0001 |
| AREA | 1340 | 8870.27 | 6.6196 | 6.68 | | 6871.69 | 798.19 | <0.0001 |
| YEAR | 1351 | 9407.85 | 6.9636 | 1.83 | | 6602.9 | 260.62 | <0.0001 |
| **MONTH +** | | | | | | | | |
| AREA | 1333 | 7528.93 | 5.6481 | 20.38 | 6.21 | 7542.36 | 727.18 | <0.0001 |
| YEAR | 1344 | 7998.98 | 5.9516 | 16.10 | | 7307.34 | 257.14 | <0.0001 |
| **MONTH + AREA** | | | | | | | | |
| YEAR | 1321 | 7298.74 | 5.5252 | 22.11 | 1.73 | 7657.46 | 230.19 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor | | |
|---|---|---|---|---|---|---|
| | | | | MONTH | AREA | YEAR |
| **MONTH+AREA+YEAR** | 4534.5 | 4539.7 | 4532.5 | <0.0001 | <0.0001 | 0.0043 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 14.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **Atlantic sharpnose shark** in SEAMAP. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**SEAMAP**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 2931 | 4050.41 | 1.3819 | | | -2025.20 | | |
| MONTH | 2924 | 3158.72 | 1.0803 | 21.83 | 21.83 | -1579.36 | 891.69 | <0.0001 |
| AREA | 2908 | 3944.82 | 1.3565 | 1.84 | | -1972.41 | 105.59 | <0.0001 |
| YEAR | 2919 | 3986.24 | 1.3656 | 1.18 | | -1993.12 | 64.17 | <0.0001 |
| **MONTH +** | | | | | | | | |
| AREA | 2901 | 2969.57 | 1.0236 | 25.93 | 4.10 | -1484.79 | 189.15 | <0.0001 |
| YEAR | 2912 | 3103.25 | 1.0657 | 22.88 | | -1551.63 | 55.47 | <0.0001 |
| **MONTH + AREA** | | | | | | | | |
| YEAR | 2889 | 2905.34 | 1.0057 | 27.22 | 1.30 | -1452.67 | 64.23 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor MONTH | AREA | YEAR |
|---|---|---|---|---|---|---|
| **MONTH+AREA+YEAR** | 13974.9 | 13980.8 | 13972.9 | <0.0001 | <0.0001 | <0.0001 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 1363 | 9668.47 | 7.0935 | | | 6472.59 | | |
| MONTH | 1356 | 8256.12 | 6.0886 | 14.17 | 14.17 | 7178.77 | 1412.35 | <0.0001 |
| AREA | 1340 | 8870.27 | 6.6196 | 6.68 | | 6871.69 | 798.19 | <0.0001 |
| YEAR | 1351 | 9407.85 | 6.9636 | 1.83 | | 6602.9 | 260.62 | <0.0001 |
| **MONTH +** | | | | | | | | |
| AREA | 1333 | 7528.93 | 5.6481 | 20.38 | 6.21 | 7542.36 | 727.18 | <0.0001 |
| YEAR | 1344 | 7998.98 | 5.9516 | 16.10 | | 7307.34 | 257.14 | <0.0001 |
| **MONTH + AREA** | | | | | | | | |
| YEAR | 1321 | 7298.74 | 5.5252 | 22.11 | 1.73 | 7657.46 | 230.19 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor MONTH | AREA | YEAR |
|---|---|---|---|---|---|---|
| **MONTH+AREA+YEAR** | 4534.5 | 4539.7 | 4532.5 | <0.0001 | <0.0001 | 0.0046 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 15.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **bonnethead** in SEAMAP. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**SEAMAP**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 2696 | 3039.26 | 1.1273 | | | -1519.63 | | |
| AREA | 2676 | 2685.6 | 1.0036 | 10.97 | 10.97 | -1342.80 | 353.66 | <0.0001 |
| MONTH | 2689 | 2846.35 | 1.0585 | 6.10 | | -1423.17 | 192.91 | <0.0001 |
| YEAR | 2684 | 2951.56 | 1.0997 | 2.45 | | -1475.78 | 87.70 | <0.0001 |
| **AREA +** | | | | | | | | |
| MONTH | 2669 | 2476.02 | 0.9277 | 17.71 | 6.73 | -1238.01 | 209.58 | <0.0001 |
| YEAR | 2664 | 2594.95 | 0.9741 | 13.59 | | -1297.47 | 90.65 | <0.0001 |
| **AREA + MONTH** | | | | | | | | |
| YEAR | 2657 | 2402.97 | 0.9044 | 19.77 | 2.07 | -1201.48 | 73.05 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: AREA | MONTH | YEAR |
|---|---|---|---|---|---|---|
| **AREA+MONTH+YEAR** | 13573.0 | 13578.9 | 13571.0 | <0.0001 | <0.0001 | <0.0001 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 676 | 3274.90 | 4.8445 | | | 733.40 | | |
| AREA | 656 | 2493.08 | 3.8004 | 21.55 | 21.55 | 1124.31 | 781.82 | <0.0001 |
| YEAR | 664 | 3085.84 | 4.6473 | 4.07 | | 827.93 | 189.06 | <0.0001 |
| MONTH | 669 | 3187.75 | 4.7649 | 1.64 | | 776.98 | 87.15 | <0.0001 |
| **AREA +** | | | | | | | | |
| YEAR | 644 | 2254.94 | 3.5015 | 27.72 | 6.17 | 1243.38 | 238.13 | <0.0001 |
| MONTH | 649 | 2350.41 | 3.6216 | 25.24 | | 1195.65 | 142.67 | <0.0001 |
| **AREA + YEAR** | | | | | | | | |
| MONTH | 637 | 2118.98 | 3.3265 | 31.33 | 3.61 | 1311.36 | 135.96 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: AREA | YEAR | MONTH |
|---|---|---|---|---|---|---|
| **AREA+YEAR+MONTH** | 2229.7 | 2234.2 | 2227.7 | <0.0001 | <0.0001 | 0.0004 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 16.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for the **small coastal shark** aggregate in the South Carolina DNR longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**SCDNR LL**

**Proportion positive**

| **Factors** | **d.f.** | **Deviance** | **Deviance/df** | **% Reduction in deviance/df** | **% Difference** | **L** | **Chi Square** | **Pr>Chi Square** |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 631 | 614.35 | 0.9736 | | | -307.18 | | |
| SEASON | 628 | 561.89 | 0.8947 | 8.10 | 8.10 | -280.95 | 52.46 | <0.0001 |
| YEAR | 626 | 605.02 | 0.9665 | 0.73 | | -302.51 | 9.33 | 0.0965 |
| **SEASON +** | | | | | | | | |
| YEAR | 623 | 549.38 | 0.8818 | 9.43 | 1.32 | -274.69 | 12.51 | 0.0284 |

**FINAL MODEL RESULTS**

| **Factors** | **Akaike's information criterion** | **Schwarz's Bayesian criterion** | **-2 Res L** | **Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON** | **YEAR** |
|---|---|---|---|---|---|
| **SEASON+YEAR** | 3176 | 3180.4 | 3174 | <0.0001 | 0.0397 |

**Positive catches**

| **Factors** | **d.f.** | **Deviance** | **Deviance/df** | **% Reduction in deviance/df** | **% Difference** | **L** | **Chi Square** | **Pr>Chi Square** |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 511 | 3807.57 | 7.4512 | | | 5582.82 | | |
| SEASON | 508 | 3100.67 | 6.1037 | 18.08 | 18.08 | 5936.27 | 706.90 | <0.0001 |
| YEAR | 506 | 3726.17 | 7.3640 | 1.17 | | 5623.52 | 81.40 | <0.0001 |
| **SEASON +** | | | | | | | | |
| YEAR | 503 | 3070.99 | 6.1053 | 18.06 | -0.02 | 5951.12 | 29.68 | <0.0001 |

**FINAL MODEL RESULTS**

| **Factors** | **Akaike's information criterion** | **Schwarz's Bayesian criterion** | **-2 Res L** | **Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON** | **YEAR** |
|---|---|---|---|---|---|
| **SEASON+YEAR** | 1374.5 | 1378.7 | 1372.5 | <0.0001 | 0.5148 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 17.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **Atlantic sharpnose shark** in the South Carolina DNR longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**SCDNR LL**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 631 | 655.63 | 1.0390 | | | -327.82 | | |
| SEASON | 628 | 618.13 | 0.9843 | 5.26 | 5.26 | -309.06 | 37.50 | <0.0001 |
| YEAR | 626 | 645.38 | 1.031 | 0.77 | | -322.69 | 10.26 | 0.0683 |
| **SEASON +** | | | | | | | | |
| YEAR | 623 | 604.18 | 0.9698 | 6.66 | 1.40 | -302.09 | 13.95 | 0.0159 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR |
|---|---|---|---|---|---|
| **SEASON+YEAR** | 3047.7 | 3052.2 | 3045.7 | <0.0001 | 0.0216 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 496 | 3555.53 | 7.1684 | | | 4587.53 | | |
| SEASON | 493 | 2961.33 | 6.0068 | 16.20 | 16.20 | 4884.63 | 594.20 | <0.0001 |
| YEAR | 491 | 3495.33 | 7.1188 | 0.69 | | 4617.63 | 60.21 | <0.0001 |
| **SEASON +** | | | | | | | | |
| YEAR | 488 | 2933.02 | 6.0103 | 16.16 | -0.05 | 4898.79 | 28.31 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR |
|---|---|---|---|---|---|
| **SEASON+YEAR** | 1375.6 | 1379.8 | 1373.6 | <0.0001 | 0.5347 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 18.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **blacknose shark** in the South Carolina DNR longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**SCDNR LL**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 631 | 792 | 1.2552 | | | -396.00 | | |
| SEASON | 628 | 736.72 | 1.1731 | 6.54 | 6.54 | -368.36 | 55.28 | <0.0001 |
| YEAR | 626 | 772.92 | 1.2347 | 1.63 | | -386.46 | 19.08 | 0.0019 |
| **SEASON +** | | | | | | | | |
| YEAR | 623 | 724.95 | 1.1636 | 7.30 | 0.76 | -362.47 | 11.77 | 0.0381 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR |
|---|---|---|---|---|---|
| **SEASON+YEAR** | 2808.2 | 2812.7 | 2806.2 | <0.0001 | 0.0550 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 201 | 297.42 | 1.4797 | | | -66.28 | | |
| SEASON | 199 | 243.51 | 1.2237 | 17.30 | 17.30 | -39.32 | 53.91 | <0.0001 |
| YEAR | 196 | 271.12 | 1.3833 | 6.51 | | -53.12 | 26.31 | <0.0001 |
| **SEASON +** | | | | | | | | |
| YEAR | 194 | 233.63 | 1.2043 | 18.61 | 1.31 | -34.38 | 9.88 | 0.0787 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR |
|---|---|---|---|---|---|
| **SEASON+YEAR** | 504.1 | 507.4 | 502.1 | <0.0001 | 0.2568 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 19.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for the **small coastal shark** aggregate in the VIMS longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**VIMS LL**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 757 | 804.42 | 1.0626 | | | -402.21 | | |
| AREA | 753 | 656.73 | 0.8721 | 17.93 | 17.93 | -328.36 | 147.70 | <0.0001 |
| SEASON | 755 | 736.04 | 0.9749 | 8.25 | | -368.02 | 68.39 | <0.0001 |
| YEAR | 726 | 767.33 | 1.0569 | 0.54 | | -383.67 | 24.05 | 0.2403 |
| **AREA +** | | | | | | | | |
| SEASON | 751 | 578.25 | 0.7700 | 27.54 | 9.61 | -289.12 | 78.48 | <0.0001 |
| YEAR | 722 | 623.75 | 0.8639 | 18.70 | | -311.87 | 23.91 | 0.2464 |
| **AREA + SEASON** | | | | | | | | |
| YEAR | 720 | 550.55 | 0.7646 | 28.04 | 0.51 | -275.27 | 19.26 | 0.5050 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: AREA | SEASON | YEAR |
|---|---|---|---|---|---|---|
| **AREA+SEASON+YEAR** | 4290.1 | 4294.7 | 4288.1 | <0.0001 | <0.0001 | 0.6791 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 163 | 1214.25 | 7.4494 | | | 794.78 | | |
| YEAR | 142 | 701.6 | 4.9408 | 33.68 | 33.68 | 731.62 | 94.24 | <0.0001 |
| SEASON | 161 | 1172.77 | 7.2843 | 2.22 | | 815.52 | 41.48 | <0.0001 |
| AREA | 159 | 1180.35 | 7.4236 | 0.35 | | 811.73 | 33.90 | <0.0001 |
| **YEAR +** | | | | | | | | |
| SEASON | 140 | 678.14 | 4.8439 | 34.98 | 1.30 | 743.34 | 23.46 | <0.0001 |
| AREA | 138 | 740.53 | 4.9549 | 33.49 | | 740.53 | 17.83 | 0.0013 |
| **YEAR + SEASON +** | | | | | | | | |
| AREA | 136 | 664.62 | 4.8869 | 34.40 | -0.58 | 750.11 | 13.52 | 0.0090 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: YEAR | SEASON |
|---|---|---|---|---|---|
| **YEAR+SEASON** | 457.9 | 460.9 | 455.9 | 0.8767 | 0.9150 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 20.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **Atlantic sharpnose shark** in the VIMS longline survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**VIMS LL**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 746 | 791.38 | 1.0608 | | | -395.69 | | |
| AREA | 742 | 647.66 | 0.8729 | 17.71 | 17.71 | -323.83 | 143.72 | <0.0001 |
| SEASON | 744 | 723.30 | 0.9722 | 8.35 | | -361.65 | 68.08 | <0.0001 |
| YEAR | 726 | 767.33 | 1.0569 | 0.37 | | -383.67 | 24.05 | 0.2403 |
| **AREA +** | | | | | | | | |
| SEASON | 740 | 569.81 | 0.7700 | 27.41 | 9.70 | -284.9 | 77.85 | <0.0001 |
| YEAR | 722 | 623.75 | 0.8639 | 18.56 | | -311.87 | 23.91 | 0.2464 |
| **AREA + SEASON** | | | | | | | | |
| YEAR | 720 | 550.55 | 0.7646 | 27.92 | 0.51 | -275.27 | 19.26 | 0.5050 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: AREA | SEASON | YEAR |
|---|---|---|---|---|---|---|
| **AREA+SEASON+YEAR** | 4290.1 | 4294.7 | 4288.1 | <0.0001 | <0.0001 | 0.6791 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 162 | 795.02 | 4.9075 | | | 677.63 | | |
| SEASON | 160 | 765.58 | 4.7849 | 2.50 | 2.50 | 692.34 | 29.43 | <0.0001 |
| AREA | 158 | 771.29 | 4.8816 | 0.53 | | 689.49 | 23.73 | <0.0001 |
| YEAR | 142 | 702.28 | 4.9457 | -0.78 | | 723.99 | 92.73 | <0.0001 |
| **SEASON +** | | | | | | | | |
| AREA | 156 | 750.31 | 4.8097 | 1.99 | -0.51 | 699.98 | 15.27 | 0.0042 |
| YEAR | 140 | 679.24 | 4.8517 | 1.14 | | 735.52 | 86.34 | <0.0001 |
| **SEASON + AREA** | | | | | | | | |
| YEAR | 136 | 665.98 | 4.8969 | 0.22 | -1.78 | 742.15 | 84.34 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR |
|---|---|---|---|---|---|
| **SEASON + YEAR** | 458.6 | 461.6 | 456.6 | 0.2009 | 0.8854 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 21.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **small coastal sharks** in the NEFSC bottom trawl survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**NEFSC Bottom Trawl**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 25000 | 7456.29 | 0.2965 | | | -3728.14 | | |
| DEPTHZONE | 25000 | 6451.36 | 0.2566 | 13.46 | 13.46 | -3225.68 | 1004.93 | <0.0001 |
| SEASON | 25000 | 6523.3 | 0.2594 | 12.51 | | -3261.65 | 932.99 | <0.0001 |
| YEAR | 25000 | 7268.73 | 0.2894 | 2.39 | | -3634.36 | 187.56 | <0.0001 |
| **DEPTHZONE +** | | | | | | | | |
| SEASON | 25000 | 6021.62 | 0.2395 | 19.22 | 5.77 | -3010.81 | 429.74 | <0.0001 |
| YEAR | 25000 | 6340.10 | 0.2525 | 14.84 | | -3170.05 | 111.26 | <0.0001 |
| **DEPTHZONE + SEASON** | | | | | | | | |
| YEAR | 25000 | 5898.86 | 0.2349 | 20.78 | 1.55 | -2949.43 | 122.76 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: DEPTHZONE | SEASON | YEAR |
|---|---|---|---|---|---|---|
| **DEPTHZONE+SEASON +YEAR** | 183126.9 | 183135.1 | 183124.9 | <0.0001 | <0.0001 | <0.0001 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 855 | 4009.92 | 4.6900 | | | 219.37 | | |
| DEPTHZONE | 850 | 3281.27 | 3.8603 | 17.69 | 17.69 | 585.69 | 725.14 | <0.0001 |
| YEAR | 821 | 3395.42 | 4.1357 | 11.82 | | 528.62 | 610.99 | <0.0001 |
| SEASON | 850 | 3893.13 | 4.5801 | 2.34 | | 279.77 | 113.28 | <0.0001 |
| **DEPTHZONE +** | | | | | | | | |
| YEAR | 818 | 2915.92 | 3.5647 | 23.99 | 6.30 | 768.37 | 365.35 | <0.0001 |
| SEASON | 847 | 3240.00 | 3.8253 | 18.44 | | 606.33 | 41.27 | <0.0001 |
| **DEPTHZONE + YEAR** | | | | | | | | |
| SEASON | 815 | 2886.81 | 3.5421 | 24.48 | 0.48 | 782.92 | 29.12 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: DEPTHZONE | YEAR | SEASON |
|---|---|---|---|---|---|---|
| **DEPTHZONE+YEAR + SEASON** | 3166.4 | 3171.1 | 3164.4 | <0.0001 | 0.0035 | 0.1960 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 22.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **Atlantic sharpnose shark** in the NEFSC bottom trawl survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**NEFSC Bottom Trawl**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 8633 | 2749.9 | 0.3185 | | | -1374.95 | | |
| DEPTHZONE | 8630 | 2253.81 | 0.2612 | 17.99 | 17.99 | -1126.9 | 496.09 | <0.0001 |
| SEASON | 8632 | 2511.04 | 0.2909 | 8.67 | | -1255.52 | 238.86 | <0.0001 |
| YEAR | 8611 | 2612.21 | 0.3034 | 4.74 | | -1306.1 | 137.69 | <0.001 |
| **DEPTHZONE +** | | | | | | | | |
| SEASON | 8629 | 2037.08 | 0.2361 | 25.87 | 7.88 | -1018.54 | 216.73 | <0.0001 |
| YEAR | 8608 | 2190.03 | 0.2544 | 20.13 | | -1095.02 | 63.78 | <0.0001 |
| **DEPTHZONE + SEASON** | | | | | | | | |
| YEAR | 8607 | 1980.18 | 0.2301 | 27.76 | 1.88 | -990.09 | 56.90 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: DEPTHZONE | SEASON | YEAR |
|---|---|---|---|---|---|---|
| **DEPTHZONE+SEASON +YEAR** | 64057.9 | 64067 | 64057.9 | <0.0001 | <0.0001 | <0.0001 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 329 | 2068.02 | 6.3049 | | | 473.94 | | |
| DEPTHZONE | 318 | 1832.21 | 5.7617 | 8.62 | 8.62 | 591.82 | 224.46 | <0.0001 |
| YEAR | 300 | 1744.83 | 5.8161 | 7.75 | | 635.51 | 311.84 | <0.0001 |
| SEASON | 320 | 2050.68 | 6.4084 | -1.64 | | 482.59 | 5.99 | 0.0144 |
| **DEPTHZONE +** | | | | | | | | |
| YEAR | 297 | 1639.73 | 5.5210 | 12.43 | 3.82 | 688.07 | 192.49 | <0.0001 |
| SEASON | 317 | 1817.93 | 5.7348 | 9.04 | | 598.96 | 14.28 | 0.0002 |
| **DEPTHZONE + YEAR** | | | | | | | | |
| SEASON | 296 | 1625.2 | 5.4906 | 12.92 | 0.48 | 695.33 | 14.52 | 0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: DEPTHZONE | YEAR | SEASON |
|---|---|---|---|---|---|---|
| **DEPTHZONE+YEAR + SEASON** | 1209.7 | 1213.4 | 1207.7 | 0.0088 | 0.5955 | 0.2285 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 23.** Deviance analysis tables showing the stepwise procedure used to develop the catch rate model for **Atlantic angel shark** in the NEFSC bottom trawl survey. Proportion positive assumed a binomial error distribution, whereas positive catch rates assumed a Poisson distribution.

**NEFSC Bottom Trawl**

**Proportion positive**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 25000 | 5147.75 | 0.2047 | | | -2573.87 | | |
| SEASON | 25000 | 4803.92 | 0.191 | 6.69 | 6.69 | -2401.96 | 343.82 | <0.0001 |
| DEPTHZONE | 25000 | 4857.08 | 0.1932 | 5.62 | | -2428.54 | 290.67 | <0.0001 |
| YEAR | 25000 | 5032.59 | 0.2004 | 2.10 | | -2516.29 | 115.16 | <0.0001 |
| **SEASON +** | | | | | | | | |
| YEAR | 25000 | 4650.45 | 0.1852 | 9.53 | 2.83 | -2325.22 | 153.48 | <0.0001 |
| DEPTHZONE | 25000 | 4668.64 | 0.1857 | 9.28 | | -2334.32 | 135.28 | <0.0001 |
| **SEASON + YEAR** | | | | | | | | |
| DEPTHZONE | 25000 | 4502.09 | 0.1793 | 12.41 | 2.88 | -2251.04 | 148.36 | <0.0001 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR | DEPTHZONE |
|---|---|---|---|---|---|---|
| **SEASON+YEAR +DEPTHZONE** | 186030.8 | 186038.9 | 186028.8 | <0.0001 | <0.0001 | <0.0001 |

**Positive catches**

| Factors | d.f. | Deviance | Deviance/df | % Reduction in deviance/df | % Difference | L | Chi Square | Pr>Chi Square |
|---|---|---|---|---|---|---|---|---|
| **NULL** | 532 | 581.85 | 1.0937 | | | -392.17 | | |
| SEASON | 527 | 537.43 | 1.0198 | 6.76 | 6.76 | -367.96 | 43.55 | <0.0001 |
| DEPTHZONE | 527 | 538.34 | 1.0215 | 6.60 | | -368.42 | 42.63 | <0.0001 |
| YEAR | 498 | 513.45 | 1.031 | 5.73 | | -355.97 | 67.52 | 0.0002 |
| **SEASON +** | | | | | | | | |
| YEAR | 495 | 470.02 | 0.9495 | 13.18 | 6.43 | -334.26 | 67.41 | 0.0003 |
| DEPTHZONE | 524 | 508.97 | 0.9713 | 11.19 | | -353.73 | 28.46 | <0.0001 |
| **SEASON + YEAR** | | | | | | | | |
| DEPTHZONE | 492 | 454.18 | 0.9231 | 15.60 | 2.41 | -326.34 | 15.84 | 0.0012 |

**FINAL MODEL RESULTS**

| Factors | Akaike's information criterion | Schwarz's Bayesian criterion | -2 Res L | Significance (Pr>Chi square) of theType 3 test of fixed effects for each individual factor: SEASON | YEAR | DEPTHZONE |
|---|---|---|---|---|---|---|
| **SEASON+YEAR +DEPTHZONE** | 1335.6 | 1339.8 | 1333.6 | 0.0001 | 0.0689 | 0.0052 |

% Difference: percent difference in deviance/df between the newly included factor and the previous factor entered into the model;
L: log likelihood; Chi Square: Pearson Chi-square statistic; Pr>Chi Square: significance level of the Chi-square statistic

**Table 24.** Trends in catch rates of small coastal sharks. Slopes and standard errors (SE) of the slopes were obtained from linear regressions of relative catch rates on year. Slopes significantly different from 0 are denoted as * (5% level), ** (1% level), and *** (0.1% level) for quick identification.

| Series | Sample size | Years | Slope | SE | P value | $r^2$ |
|---|---|---|---|---|---|---|
| **Small coastal** | | | | | | |
| Oregon II [1] | 29 | 1972-2000 | -0.0213** | 0.0065 | 0.0027 | 0.29 |
| SCDNR LL [1] | 6 | 1995-2000 | -0.0078 | 0.0137 | 0.6022 | 0.07 |
| Recreational | 18 | 1981-1998 | 0.0398** | 0.0124 | 0.0054 | 0.39 |
| NMFS LL PC [1] | 8 | 1993-2000 | 0.0435 | 0.0346 | 0.2556 | 0.21 |
| NMFS GN PC | 5 | 1996-2000 | -0.0734 | 0.0769 | 0.3939 | 0.18 |
| DGNOP [2] | 7 | 1993-2001 | 0.0588* | 0.0148 | 0.0108 | 0.76 |
| SEAMAP | 13 | 1989-2001 | 0.0389 | 0.0191 | 0.0668 | 0.27 |
| VIMS LL [2] | 21 | 1974-2001 | -0.0101 | 0.0115 | 0.3914 | 0.04 |
| NEFSC Trawl [1] | 33 | 1968-2000 | -0.0142** | 0.0045 | 0.0045 | 0.23 |
| **Atlantic sharpnose** | | | | | | |
| Oregon II [1] | 29 | 1972-2000 | -0.0168* | 0.0073 | 0.0291 | 0.16 |
| VIMS LL [2] | 21 | 1974-2001 | -0.0103 | 0.0115 | 0.3805 | 0.04 |
| SCDNR LL [1] | 6 | 1995-2000 | -0.0067 | 0.0164 | 0.7048 | 0.04 |
| NMFS NE LL [2] | 5 | 1986-1998 | -0.1100 | 0.0891 | 0.2845 | 0.28 |
| Recreational | 18 | 1981-1998 | 0.0640** | 0.0169 | 0.0016 | 0.47 |
| NMFS SE LL ATL [2] | 4 | 1995-2000 | 0.2566 | 0.1359 | 0.1997 | 0.64 |
| NMFS SE LL EGM [2] | 5 | 1995-2000 | 0.1006 | 0.1853 | 0.6251 | 0.09 |
| NMFS SE LL WGM [2] | 5 | 1995-2000 | 0.0986 | 0.0877 | 0.3425 | 0.30 |
| NMFS LL PC [1] | 8 | 1993-2000 | 0.0532 | 0.0430 | 0.2625 | 0.20 |
| NMFS GN PC [1] | 5 | 1996-2000 | -0.0177 | 0.0368 | 0.6557 | 0.05 |
| DGNOP [1,2] | 7 | 1993-2001 | 0.0614 | 0.0319 | 0.1125 | 0.42 |
| SEAMAP | 13 | 1989-2001 | 0.0337 | 0.0214 | 0.1439 | 0.18 |
| NEFSC Trawl [2] | 22 | 1974-2000 | 0.0059 | 0.0222 | 0.7927 | 0.004 |
| **Bonnethead** | | | | | | |
| Oregon II | 29 | 1972-2000 | -0.1337*** | 0.0236 | 0.0000052 | 0.54 |
| Recreational | 18 | 1981-1998 | -0.0195 | 0.0206 | 0.3578 | 0.05 |
| NMFS GN PC [1] | 6 | 1996-2001 | -0.0498 | 0.0706 | 0.5193 | 0.11 |
| DGNOP [1,2] | 7 | 1993-2001 | 0.0145 | 0.0112 | 0.2532 | 0.25 |
| SEAMAP | 13 | 1989-2001 | 0.0100 | 0.0343 | 0.7761 | 0.01 |
| **Blacknose** | | | | | | |
| Recreational | 18 | 1981-1998 | 0.0574 | 0.0400 | 0.1710 | 0.11 |
| NMFS SE LL EGM [1,2] | 5 | 1995-2000 | 0.0687 | 0.0300 | 0.1060 | 0.64 |
| NMFS SE LL WGM [1,2] | 5 | 1995-2000 | 0.0712 | 0.0557 | 0.2913 | 0.35 |
| NMFS LL PC | 8 | 1993-2000 | 0.1742 | 0.1326 | 0.2370 | 0.22 |
| NMFS GN PC | 5 | 1996-2000 | -0.2570 | 0.1607 | 0.1849 | 0.39 |
| Oregon II | 29 | 1972-2000 | -0.0382 | 0.0416 | 0.3666 | 0.03 |

**Table 24.** (continued).

| Series | Sample size | Years | Slope | SE | P value | $r^2$ |
|---|---|---|---|---|---|---|
| **Blacknose** (continued) | | | | | | |
| DGNOP [2] | 7 | 1993-2001 | 0.0310 | 0.0339 | 0.4031 | 0.14 |
| SCDNR LL | 6 | 1995-2000 | -0.0702 | 0.0747 | 0.4004 | 0.18 |
| **Finetooth** | | | | | | |
| Recreational | 18 | 1981-1998 | 0.0431 | 0.0781 | 0.5884 | 0.02 |
| NMFS SE LL WGM [2] | 3 | 1995-1999 | 0.3448 | 0.3982 | 0.5456 | 0.43 |
| NMFS LL PC [1] | 8 | 1993-2000 | -0.2350 | 0.1255 | 0.1103 | 0.37 |
| NMFS GN PC | 6 | 1996-2001 | -0.1061 | 0.1259 | 0.4471 | 0.15 |
| DGNOP [2] | 7 | 1993-2001 | 0.0338* | 0.0113 | 0.0305 | 0.64 |
| **Angel** | | | | | | |
| NEFSC Trawl [1] | 33 | 1968-2000 | -0.0232*** | 0.0044 | 0.00001 | 0.47 |

[1] Indicates that the dependent variable (catch rate) was log-transformed.
[2] Indicates that there are missing data for some years.

**Table 25.** Statistical distributions and values of demographic traits (age at maturity, lifespan, fecundity, and natural mortality) used in Monte Carlo simulation of the intrinsic rate of population increase (r) of four species of small coastal sharks through a modified demographic technique. Variation in the values represents uncertainty.

| Species | Maximum size (cm total length) | Age at maturity (years) [a] | Lifespan (years) [b] | Fecundity [c] | Natural mortality [d] | r [e] |
|---|---|---|---|---|---|---|
| Atlantic sharpnose | 107 | uniform (2.4-4.0) | custom (9, 12) | uniform [4-6] | 0.228-0.687 | 0.058 [0.057] (0.041-0.074) |
| Bonnethead | 104-124 | uniform (1.9-3.5) | custom (7, 10) | normal (7.5,2.5) [3-15] | 0.203-0.867 | 0.064 [0.063] (0.039-0.086) |
| Blacknose | 130-154 | uniform (3.2-6.7) | custom (9, 13) | uniform [4-6] | 0.171-0.516 | 0.037 [0.036] (0.018-0.057) |
| Finetooth | 160 | triangular (3.3,4.3,5.3) | custom (8, 11) | normal (4.036,0.793) [2-6] | 0.174-0.528 | 0.039 [0.039] (0.024-0.053) |

[a] For the uniform distribution the range is shown; for the triangular distribution values in parentheses are low, likeliest, and high.
[b] Maximum empirical age. The assumed distribution was a linearly decreasing custom distribution scaled to a total relative probability of 1. The highest empirical value of lifespan was taken as the likeliest value and the least likely value was set by adding approximately 30% to the likeliest value. Likeliest and least likely values are given in parentheses.
[c] Values in parentheses are mean and SD (normal distribution) and values in brackets are the range (uniform distribution). All values extracted from these distributions were divided by two to account for an assumed 1:1 male to female embryo ratio and then by two again to account for a biennial reproductive cycle for the blacknose and finetooth sharks.
[d] Range of instantaneous natural mortality values obtained through five indirect life-history methods (see text for an explanation).
[e] Intrinsic rate of population increase. Values shown are the mean, median (in brackets), and 95% confidence intervals expressed as the 2.5th and 97.5th percentiles (in parentheses).

**Table 26.** Posterior means and summary statistics for several population parameters and management quantities for the **small coastal shark aggregate**. Results for the base-case scenario are shown for the Bayesian surplus production models using the SIR algorithm with weighting method 1 (equal weighting scenario in which the variance is an estimable parameter for all series; first row) and weighting method 2 (MLE estimate of variance for each series; second row), and the Gibbs sampler (third and fourth rows). Results of alternative scenarios are shown for the Bayesian SPM with the Gibbs sampler only. Values of K, MSY, and $B_{2001}$ are millions of lb dw.

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}$/K |
|---|---|---|---|---|---|---|
| Base-case | | 104.4 (18) [b] | 0.074 (20) | 1.9 (23) | 63.7 (33) | 0.60 (17) |
| | | 127.4 (12) [b] | 0.077 (20) | 2.4 (21) | 89.4 (19) | 0.70 (9) |
| | | 121.5 (14) [b] | 0.074 (20) | 2.2 (24) | 83.8 (16) | 0.70 (17) |
| | | [84.8-148.4] [c] | [0.049-0.106] | [1.3-3.4] | [62.3-115.2] | [0.50-0.97] |
| Scenario 1 | 9 series scaled | 112.0 (20) | 0.074 (20) | 2.1 (26) | 72.1 (30) | 0.64 (21) |
| | | [68.9-147.7] | [0.049-0.107] | [1.1-2.1] | [36.0-120.8] | [0.41-0.92] |
| Scenario 2 | 8 series (excluding Oregon II) | 119.2 (15) | 0.075 (20) | 2.2 (24) | 85.9 (16) | 0.73 (17) |
| | | [82.7-148.1] | [0.049-0.108] | [1.3-3.4] | [63.8-119.7] | [0.52-1.00] |
| Scenario 3 | 8 series (excluding Recreational) | 127.0 (13) | 0.073 (20) | 2.3 (23) | 93.3 (18) | 0.74 (17) |
| | | [91.4-149.0] | [0.049-0.105] | [1.4-3.5] | [67.7-133.9] | [0.53-1.03] |
| Scenario 4 | 8 series (excluding NMFS LL PC) | 122.0 (14) | 0.073 (20) | 2.2 (24) | 83.1 (15) | 0.69 (17) |
| | | [84.8-148.5] | [0.049-0.106] | [1.3-3.4] | [62.2-112.8] | [0.50-0.96] |
| Scenario 5 | 8 series (excluding NMFS GN PC) | 121.6 (15) | 0.074 (19) | 2.2 (24) | 84.8 (16) | 0.71 (17) |
| | | [83.1-148.4] | [0.049-0.106] | [1.3-3.4] | [63.0-115.4] | [0.51-0.99] |
| Scenario 6 | 8 series (excluding DGNOP) | 121.8 (14) | 0.073 (20) | 2.2 (23) | 82.7 (15) | 0.69 (16) |
| | | [85.9-148.4] | [0.049-0.105] | [1.3-3.4] | [62.2-112.6] | [0.50-0.93] |
| Scenario 7 | 8 series (excluding SCLL) | 90.2 (25) | 0.077 (20) | 1.7 (30) | 49.0 (26) | 0.56 (25) |
| | | [51.5-140.2] | [0.050-0.111] | [0.8-2.9] | [31.8-82.5] | [0.33-0.87] |
| Scenario 8 | 8 series (excluding SEAMAP) | 119.3 (16) | 0.074 (20) | 2.2 (25) | 80.9 (16) | 0.69 (19) |
| | | [78.8-148.3] | [0.049-0.106] | [1.2-3.4] | [59.3-112.7] | [0.48-0.98] |

**Table 26.** (continued)

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Scenario 9 | 8 series (excluding VIMS LL) | 122.6 (14) [86.4-148.6] | 0.073 (20) [0.049-0.105] | 2.2 (24) [1.3-3.4] | 82.3 (15) [61.0-110.9] | 0.68 (17) [0.49-0.94] |
| Scenario 10 | 8 series (excluding NEFSC Bt. Tr.) | 119.0 (15) [83.4-147.8] | 0.075 (20) [0.049-0.108] | 2.2 (24) [1.3-3.4] | 85.4 (16) [63.9-118.4] | 0.73 (16) [0.53-0.98] |
| Scenario 11 | Uniform prior on K | 123.7 (14) [87.4-148.7] | 0.074 (20) [0.049-0.106] | 2.3 (24) [1.3-3.4] | 84.6 (16) [62.7-117.1] | 0.69 (17) [0.50-0.96] |
| Scenario 12 | Mean r = 0.15 | 114.5 (15) [81.7-146.8] | 0.147 (19) [0.100-0.207] | 4.2 (22) [2.6-6.3] | 84.6 (16) [62.3-115.5] | 0.75 (14) [0.55-0.96] |
| Scenario 13 | Mean r = 0.10 | 119.1 (14) [85.0-147.9] | 0.103 (19) [0.069-0.146] | 3.0 (23) [1.8-4.6] | 84.2 (16) [62.9-115.5] | 0.71 (15) [0.52-0.95] |
| Scenario 14 | Mean r = 0.05 | 122.5 (15) [83.4-148.7] | 0.053 (20) [0.035-0.076] | 1.6 (25) [0.9-2.5] | 82.9 (16) [61.7-114.3] | 0.69 (18) [0.49-0.98] |
| Scenario 15 | Bounds of prior for P72 = 0.5-2.0 | 122.1 (14) [86.3-148.5] | 0.074 (20) [0.049-0.106] | 2.2 (24) [1.3-3.4] | 83.3 (15) [62.2-113.5] | 0.69 (17) [0.49-0.94] |
| Scenario 16 | Bounds of prior for P72 = 0.1-2.0 | 121.9 (14) [86.6-148.4] | 0.074 (20) [0.049-0.106] | 2.2 (24) [1.3-3.4] | 83.6 (15) [62.7-113.5] | 0.69 (16) [0.50-0.94] |
| Scenario 17 | Range of prior on log of K=5-60 million | 56.2 (6) [47.0-59.9] | 0.069 (20) [0.046-0.101] | 1.0 (21) [0.6-1.4] | 61.8 (16) [40.9-81.0] | 1.10 (16) [0.74-1.45] |

[a] The priors for the base-case scenario were: uniform on the logarithm of K, ranging from 5 to 150 million lb dw; lognormal for r with mean=0.07 and SD in the logarithm of r =0.20; and lognormal for $P_{72}$ with mean=1.0 and SD in the logarithm of $P_{72}$=0.2. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 27.** Posterior means and summary statistics for several population parameters and management quantities for the **Atlantic sharpnose shark**. Results for the base-case scenario are shown for the Bayesian surplus production models using the SIR algorithm with weighting method 1 (equal weighting scenario in which the variance is an estimable parameter for all series; first row) and weighting method 2 (MLE estimate of variance for each series; second row), and the Gibbs sampler (third and fourth rows). Results of alternative scenarios are shown for the Bayesian SPM with the Gibbs sampler only. Values of K, MSY, and $B_{2001}$ are millions of lb dw.

| **Scenario** | **Description of priors** [a] | **K** | **r** | **MSY** | $\mathbf{B_{2001}}$ | $\mathbf{B_{2001}/K}$ |
|---|---|---|---|---|---|---|
| Base-case | | 82.3 (15) [b] | 0.084 (23) | 1.4 (63) | 53.6 (24) | 0.64 (12) |
| | | 86.1 (11) [b] | 0.090 (18) | 1.7 (37) | 60.1 (17) | 0.69 (17) |
| | | 86.6 (11) [b] | 0.086 (20) | 1.9 (22) | 73.2 (13) | 0.85 (13) |
| | | [65.6-99.4] [c] | [0.057-0.125] | [1.1-2.8] | [56.7-93.4] | [0.66-1.11] |
| Scenario 1 | 13 series scaled | 77.6 (18) | 0.088 (20) | 1.7 (25) | 61.1 (27) | 0.79 (19) |
| | | [48.8-98.8] | [0.058-0.127] | [1.0-2.6] | [32.9-95.6] | [0.51-1.10] |
| Scenario 2 | 12 series excluding | 85.9 (11) | 0.088 (20) | 1.9 (23) | 74.1 (12) | 0.87 (13) |
| | Oregon II) | [64.2-99.3] | [0.057-0.127] | [1.1-2.8] | [58.3-94.4] | [0.68-1.13] |
| Scenario 3 | 12 series excluding | 65.5 (20) | 0.090 (20) | 1.5 (25) | 44.3 (23) | 0.69 (20) |
| | SCLL) | [43.1-94.4] | [0.059-0.130] | [0.8-2.3] | [30.2-69.4] | [0.45-0.99] |
| Scenario 4 | 12 series (excluding | 86.8 (11) | 0.086 (20) | 1.9 (22) | 74.4 (13) | 0.86 (13) |
| | NMFS LL NE) | [65.9-99.4] | [0.057-0.125] | [1.1-2.8] | [57.4-95.8] | [0.67-1.13] |
| Scenario 5 | 12 series (excluding | 88.9 (9) | 0.086 (20) | 1.9 (22) | 77.1 (13) | 0.87 (13) |
| | Recreational) | [69.7-99.6] | [0.057-0.124] | [1.2-2.8] | [60.3-99.6] | [0.68-1.13] |
| Scenario 6 | 12 series (excluding | 87.2 (10) | 0.086 (20) | 1.9 (22) | 72.4 (13) | 0.84 (13) |
| | NMFS LL SE ATL) | [66.4-99.4] | [0.057-0.125] | [1.2-2.8] | [56.2-92.3] | [0.65-1.09] |
| Scenario 7 | 12 series (excluding | 87.2 (10) | 0.086 (20) | 1.9 (22) | 73.4 (12) | 0.85 (13) |
| | NMFS LL SE EGM) | [66.0-99.4] | [0.057-0.125] | [1.1-2.8] | [58.1-92.6] | [0.67-1.10] |
| Scenario 8 | 12 series (excluding | 86.2 (11) | 0.086 (20) | 1.9 (23) | 72.1 (13) | 0.84 (14) |
| | NMFS LL SE WGM) | [65.1-99.3] | [0.057-0.125] | [1.1-2.8] | [56.0-92.0] | [0.65-1.10] |

**Table 27.** (continued)

| Scenario | Description of Priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Scenario 9 | 12 series (excluding NMFS LL PC) | 87.3 (10) [67.4-99.4] | 0.086 (20) [0.057-0.125] | 1.9 (22) [1.2-2.8] | 72.9 (12) [57.1-92.6] | 0.84 (13) [0.66-1.08] |
| Scenario 10 | 12 series (excluding NMFS GN PC) | 86.5 (11) [65.6-99.4] | 0.086 (20) [0.057-0.125] | 1.9 (22) [1.1-2.8] | 74.0 (13) [57.3-95.1] | 0.86 (14) [0.67-1.12] |
| Scenario 11 | 12 series (excluding DGNOP) | 87.3 (10) [67.4-99.4] | 0.087 (20) [0.057-0.125] | 1.9 (22) [1.1-2.8] | 72.9 (12) [56.5-92.8] | 0.84 (13) [0.66-1.07] |
| Scenario 12 | 12 series (excluding SEAMAP) | 86.3 (11) [64.1-99.4] | 0.086 (20) [0.057-0.124] | 1.9 (22) [1.1-2.7] | 72.3 (13) [55.9-93.2] | 0.84 (14) [0.65-1.13] |
| Scenario 13 | 12 series (excluding VIMS LL) | 87.0 (10) [66.2-99.4] | 0.086 (20) [0.057-0.125] | 1.9 (22) [1.1-2.8] | 73.1 (13) [56.2-93.3] | 0.85 (13) [0.66-1.11] |
| Scenario 14 | 12 series (excluding NEFSS Bt. Tr.) | 87.4 (10) [67.4-99.4] | 0.086 (20) [0.057-0.125] | 1.9 (22) [1.2-2.8] | 72.0 (12) [56.0-91.2] | 0.83 (12) [0.65-1.06] |
| Scenario 15 | Uniform prior on K | 73.6 (12) [57.5-93.5] | 0.086 (20) [0.057-0.125] | 1.9 (22) [1.1-2.8] | 87.5 (10) [66.7-99.5] | 0.85 (13) [0.66-1.10] |
| Scenario 16 | Mean r = 0.20 | 82.1 (12) [63.0-98.5] | 0.202 (19) [0.137-0.286] | 4.1 (21) [2.7-6.0] | 74.3 (12) [57.0-93.4] | 0.91 (9) [0.75-1.07] |
| Scenario 17 | Mean r = 0.10 | 86.2 (10) [66.2-99.3] | 0.107 (20) [0.072-0.153] | 2.3 (21) [1.5-3.4] | 73.4 (12) [57.0-93.1] | 0.86 (12) [0.67-1.08] |
| Scenario 18 | Mean r = 0.05 | 86.5 (11) [64.1-99.4] | 0.054 (21) [0.035-0.079] | 1.2 (24) [0.7-1.8] | 73.3 (13) [56.6-95.3] | 0.85 (16) [0.64-1.17] |
| Scenario 19 | Bounds of prior for P72 = 0.5-2.0 | 86.7 (11) [66.1-99.4] | 0.086 (20) [0.057-0.125] | 1.9 (22) [1.1-2.8] | 73.1 (13) [56.5-93.6] | 0.85 (13) [0.66-1.11] |

**Table 27.** (continued)

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Scenario 20 | Range of prior on log of K=5-40 million | 37.5 (6) [31.5-39.9] | 0.077 (21) [0.051-0.114] | 0.7 (22) [0.5-1.1] | 52.6 (19) [34.0-71.7] | 1.40 (19) [0.90-1.93] |

[a] The priors for the base-case scenario were: uniform on the logarithm of K, ranging from 5 to 100 million lb dw; lognormal for r with mean=0.08 and SD in the logarithm of r =0.20; and lognormal for $P_{72}$ with mean=1.0 and SD in the logarithm of $P_{72}$=0.2. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 28.** Posterior means and summary statistics for several population parameters and management quantities for the **bonnethead**. Results for the base-case scenario are shown for the Bayesian surplus production models using the SIR algorithm with weighting method 1 (equal weighting scenario in which the variance is an estimable parameter for all series; first row) and weighting method 2 (MLE estimate of variance for each series; second row), and the Gibbs sampler (third and fourth rows). Results of alternative scenarios are shown for the Bayesian SPM with the Gibbs sampler only. Values of K, MSY, and $B_{2001}$ are millions of lb dw.

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Base-case | | 20.8 (39) [b] | 0.101 (20) | 0.7 (22) | 15.3 (55) | 0.69 (22) |
| | | 23.4 (35) [b] | 0.102 (20) | 0.6 (39) | 18.2 (47) | 0.74 (17) |
| | | 18.3 (23) [b] | 0.105 (19) | 0.5 (28) | 13.4 (30) | 0.73 (15) |
| | | [12.5-29.6] [c] | [0.070-0.152] | [0.3-0.8] | [8.3-24.4] | [0.52-0.97] |
| Scenario 1 | 4 series scaled | 23.6 (34) | 0.104 (20) | 0.6 (39) | 18.7 (45) | 0.77 (18) |
| | | [10.6-38.8] | [0.069-0.151] | [0.3-1.2] | [5.5-36.1] | [0.47-1.03] |
| Scenario 2 | 3 series (excluding Recreational) | 26.2 (27) | 0.103 (20) | 0.7 (33) | 21.5 (35) | 0.81 (16) |
| | | [15.1-39.1] | [0.068-0.150] | [0.3-1.2] | [10.5-37.5] | [0.57-1.07] |
| Scenario 3 | 3 series (excluding NMFS GN PC) | 18.5 (23) | 0.105 (20) | 0.5 (27) | 13.6 (29) | 0.73 (16) |
| | | [12.6-29.5] | [0.070-0.151] | [0.3-0.8] | [8.6-24.1] | [0.52-0.98] |
| Scenario 4 | 3 series (excluding DGNOP) | 17.7 (22) | 0.103 (20) | 0.5 (27) | 12.2 (28) | 0.69 (16) |
| | | [12.2-27.4] | [0.068-0.101] | [0.3-0.7] | [7.5-20.9] | [0.48-0.91] |
| Scenario 5 | 3 series (excluding SEAMAP) | 9.4 (22) | 0.119 (22) | 0.3 (22) | 3.4 (57) | 0.35 (42) |
| | | [6.3-9.1] | [0.076-0.116] | [0.2-0.4] | [0.8-8.3] | [0.10-0.67] |
| Scenario 6 | Uniform prior on K | 19.1 (23) | 0.104 (20) | 0.5 (28) | 13.8 (30) | 0.72 (16) |
| | | [12.9-30.7] | [0.069-0.152] | [0.3-0.8] | [8.5-25.2] | [0.51-0.95] |
| Scenario 7 | Mean r = 0.20 | 15.8 (23) | 0.209 (20) | 0.8 (20) | 13.2 (27) | 0.83 (10) |
| | | [11.0-25.5] | [0.139-0.302] | [0.5-1.4] | [8.5-22.8] | [0.67-0.99] |
| Scenario 8 | Mean r = 0.10 | 16.7 (22) | 0.157 (20) | 0.6 (27) | 13.3 (27) | 0.79 (12) |
| | | [11.6-26.2] | [0.104-0.228] | [0.4-1.1] | [8.5-22.7] | [0.60-0.99] |

**Table 28.** (continued)

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Scenario 9 | Mean r = 0.05 | 20.6 (23) [13.3-32.7] | 0.052 (20) [0.034-0.076] | 0.3 (29) [0.1-0.4] | 13.0 (30) [7.8-23.1] | 0.64 (21) [0.40-0.94] |
| Scenario 10 | Bounds of prior for P72 = 0.5-2.0 | 18.1 (22) [12.4-28.5] | 0.105 (19) [0.070-0.152] | 0.5 (27) [0.3-0.8] | 13.2 (28) [8.3-22.8] | 0.73 (15) [0.52-0.96] |
| Scenario 11 | Range of prior on log of K=1-20 million | 16.3 (13) [12.1-19.7] | 0.106 (19) [0.071-0.153] | 0.4 (22) [0.3-0.6] | 11.9 (18) [8.1-16.4] | 0.73 (14) [0.55-0.95] |
| Scenario 12 | Range of prior on log of K=1-60 million | 18.3 (24) [12.5-29.7] | 0.105 (20) [0.070-0.152] | 0.5 (29) [0.3-0.8] | 13.3 (30) [8.3-24.1] | 0.73 (15) [0.52-0.95] |

[a] The priors for the base-case scenario were: uniform on the logarithm of K, ranging from 1 to 40 million lb dw; lognormal for r with mean=0.10 and SD in the logarithm of r =0.20; and lognormal for $P_{72}$ with mean=1.0 and SD in the logarithm of $P_{72}$=0.2. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 29.** Posterior means and summary statistics for several population parameters and management quantities for the **blacknose shark**. Results for the base-case scenario are shown for the Bayesian surplus production models using the SIR algorithm with weighting method 1 (equal weighting scenario in which the variance is an estimable parameter for all series; first row) and weighting method 2 (MLE estimate of variance for each series; second row), and the Gibbs sampler (third and fourth rows). Results of alternative scenarios are shown for the Bayesian SPM with the Gibbs sampler only. Values of K, MSY, and $B_{2001}$ are millions of lb dw.

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}$/K |
|---|---|---|---|---|---|---|
| Base-case | | 10.2 (63) [b]<br>12.7 (48) [b]<br>10.9 (31) [b]<br>[6.1-19.7] [c] | 0.060 (19)<br>0.060 (20)<br>0.061 (20)<br>[0.041-0.089] | 0.152 (67)<br>0.191 (53)<br>0.167 (37)<br>[0.079-0.322] | 9.1 (70)<br>11.6 (52)<br>10.4 (29)<br>[6.4-18.4] | 0.83 (18)<br>0.88 (11)<br>0.98 (18)<br>[0.69-1.37] |
| Scenario 1 | 7 series scaled | 12.3 (56)<br>[3.1-24.0] | 0.061 (20)<br>[0.041-0.089] | 0.189 (54)<br>[0.045-0.415] | 12.1 (56)<br>[2.5-26.6] | 0.97 (19)<br>[0.65-1.36] |
| Scenario 2 | 6 series (excluding SCLL) | 3.1 (58)<br>[0.9-7.7] | 0.062 (20)<br>[0.041-0.091] | 0.049 (63)<br>[0.013-0.126] | 2.5 (67)<br>[0.7-6.9] | 0.81 (30)<br>[0.44-1.39] |
| Scenario 3 | 6 series (excluding Recreational) | 13.8 (33)<br>[7.1-23.7] | 0.061 (20)<br>[0.041-0.089] | 0.212 (39)<br>[0.092-0.408] | 13.5 (33)<br>[7.5-24.1] | 0.99 (16)<br>[0.71-1.35] |
| Scenario 4 | 6 series (excluding NMFS LL SEE) | 10.8 (31)<br>[6.1-19.4] | 0.061 (16)<br>[0.041-0.089] | 0.165 (37)<br>[0.079-0.320] | 10.0 (29)<br>[6.2-17.9] | 0.95 (17)<br>[0.66-1.29] |
| Scenario 5 | 6 series (excluding NMFS LL SEW) | 10.7 (30)<br>[6.2-19.3] | 0.062 (16)<br>[0.041-0.090] | 0.164 (37)<br>[0.080-0.318] | 10.1 (29)<br>[6.3-18.0] | 0.97 (16)<br>[0.69-1.33] |
| Scenario 6 | 6 series (excluding NMFS LL PC) | 11.8 (32)<br>[6.5-21.8] | 0.061 (20)<br>[0.040-0.089] | 0.181 (38)<br>[0.084-0.355] | 11.4 (33)<br>[6.7-21.4] | 0.98 (17)<br>[0.69-1.35] |
| Scenario 7 | 6 series (excluding NMFS GN PC) | 11.0 (31)<br>[6.1-20.5] | 0.061 (20)<br>[0.041-0.089] | 0.169 (38)<br>[0.079-0.330] | 10.7 (30)<br>[6.6-19.3] | 0.99 (18)<br>[0.70-1.41] |
| Scenario 8 | 6 series (excluding DGNOP) | 10.9 (30)<br>[6.3-19.4] | 0.062 (20)<br>[0.041-0.089] | 0.168 (37)<br>[0.082-0.323] | 10.2 (29)<br>[6.3-18.0] | 0.95 (16)<br>[0.68-1.30] |

**Table 29.** (continued)

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Scenario 9 | Mean r = 0.12 | 10.7 (28)<br>[6.5-18.5] | 0.123 (20)<br>[0.081-0.179] | 0.329 (34)<br>[0.168-0.614] | 10.4 (28)<br>[6.5-18.5] | 0.98 (12)<br>[0.77-1.22] |
| Scenario 10 | Mean r = 0.03 | 10.4 (32)<br>[5.6-19.4] | 0.031 (20)<br>[0.020-0.045] | 0.080 (29)<br>[0.037-0.160] | 10.4 (29)<br>[6.5-18.5] | 1.03 (22)<br>[0.67-1.57] |
| Scenario 11 | Range of prior on log of K=0.5-40 million | 10.9 (33)<br>[6.1-19.8] | 0.061 (20)<br>[0.041-0.089] | 0.168 (39)<br>[0.079-0.329] | 10.6 (31)<br>[6.5-19.0] | 0.98 (17)<br>[0.71-1.37] |
| Scenario 12 | Range of prior on log of K=0.5-60 million | 11.1 (33)<br>[6.2-20.8] | 0.061 (20)<br>[0.041-0.089] | 0.170 (39)<br>[0.080-0.342] | 10.6 (32)<br>[6.5-19.7] | 0.98 (17)<br>[0.70-1.38] |
| Scenario 13 | Catch in 1984, 1985, 1990, 1991=mean catch (1983-1994) | 11.0 (31)<br>[6.2-19.8] | 0.061 (20)<br>[0.041-0.089] | 0.169 (37)<br>[0.080-0.325] | 10.5 (29)<br>[6.5-18.6] | 0.97 (18)<br>[0.68-1.38] |

[a] The priors for the base-case scenario were: uniform on the logarithm of K, ranging from 0.5 to 25 million lb dw; lognormal for r with mean=0.06 and SD in the logarithm of r =0.20; and lognormal for $P_{72}$ with mean=1.0 and SD in the logarithm of $P_{72}$=0.2. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 30.** Posterior means and summary statistics for several population parameters and management quantities for the **finetooth shark**. Results for the base-case scenario are shown for the Bayesian surplus production models using the SIR algorithm with weighting method 1 (equal weighting scenario in which the variance is an estimable parameter for all series; first row) and weighting method 2 (MLE estimate of variance for each series; second row), and the Gibbs sampler (third and fourth rows). Results of alternative scenarios are shown for the Bayesian SPM with the Gibbs sampler only. Values of K, MSY, and $B_{2001}$ are millions of lb dw.

| **Scenario** | **Description of priors** [a] | **K** | **r** | **MSY** | **$B_{2001}$** | **$B_{2001}/K$** |
|---|---|---|---|---|---|---|
| Base-case | | 4.5 (101) [b] | 0.060 (20) | 0.068 (106) | 3.4 (136) | 0.49 (69) |
| | | 11.7 (40) [b] | 0.061 (20) | 0.177 (46) | 10.2 (45) | 0.85 (45) |
| | | 3.3 (57) [b] | 0.062 (20) | 0.051 (61) | 2.3 (79) | 0.64 (32) |
| | | [1.3-8.3] [c] | [0.041-0.090] | [0.018-0.134] | [0.4-7.2] | [0.25-1.05] |
| Scenario 1 | 5 series scaled | 9.5 (51) | 0.061 (20) | 0.146 (56) | 8.8 (59) | 0.89 (21) |
| | | [2.4-19.2] | [0.041-0.089] | [0.034-0.329] | [1.5-20.1] | [0.54-1.28] |
| Scenario 2 | 4 series (excluding Recreational) | 7.2 (56) | 0.062 (20) | 0.111 (61) | 6.3 (65) | 0.84 (21) |
| | | [2.0-17.5] | [0.041-0.089] | [0.029-0.283] | [1.1-16.8] | [0.48-1.20] |
| Scenario 3 | 4 series (excluding NMFS LL SEW) | 3.1 (58) | 0.062 (20) | 0.048 (62) | 2.1 (84) | 0.62 (34) |
| | | [1.2-7.9] | [0.041-0.090] | [0.017-0.128] | [0.3-6.8] | [0.20-1.03] |
| Scenario 4 | 4 series (excluding NMFS LL PC) | 4.2 (63) | 0.062 (20) | 0.064 (67) | 3.2 (81) | 0.73 (27) |
| | | [1.5-11.6] | [0.041-0.090] | [0.020-0.186] | [0.6-10.6] | [0.35-1.13] |
| Scenario 5 | 4 series (excluding NMFS GN PC) | 3.6 (59) | 0.062 (20) | 0.055 (63) | 2.6 (78) | 0.67 (31) |
| | | [1.3-9.3] | [0.041-0.090] | [0.018-0.148] | [0.4-8.1] | [0.25-1.10] |
| Scenario 6 | 4 series (excluding DGNOP) | 1.4 (39) | 0.062 (20) | 0.021 (43) | 0.2 (196) | 0.13 (157) |
| | | [0.8-2.7] | [0.041-0.090] | [0.011-0.043] | [0.0-1.4] | [0.00-1.41] |
| Scenario 7 | Mean r = 0.12 | 3.1 (59) | 0.125 (20) | 0.098 (63) | 2.4 (94) | 0.66 (31) |
| | | [1.3-7.9] | [0.082-0.181] | [0.036-0.253] | [0.4-7.8] | [0.25-1.06] |
| Scenario 8 | Mean r = 0.03 | 3.4 (60) | 0.031 (20) | 0.026 (64) | 2.4 (83) | 0.66 (36) |
| | | [1.3-9.0] | [0.020-0.045] | [0.009-0.072] | [0.4-7.7] | [0.23-1.17] |

**Table 30.** (continued)

| Scenario | Description of priors [a] | K | r | MSY | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|
| Scenario 9 | Range of prior on log of K=0.5-40 million | 3.4 (62) [1.3-9.1] | 0.062 (20) [0.041-0.090] | 0.053 (65) [0.018-0.145] | 2.4 (85) [0.4-7.8] | 0.64 (31) [0.26-1.05] |
| Scenario 10 | Range of prior on log of K=0.5-60 million | 3.4 (70) [1.3-9.1] | 0.062 (20) [0.041-0.090] | 0.052 (75) [0.018-0.146] | 2.4 (94) [0.4-7.8] | 0.66 (31) [0.25-1.06] |
| Scenario 11 | Catch in 1990=mean catch (1986-1994) | 3.4 (58) [1.3-8.7] | 0.062 (20) [0.041-0.090] | 0.052 (61) [0.018-0.138] | 2.3 (80) [0.4-7.4] | 0.64 (32) [0.23-1.03] |

[a] The priors for the base-case scenario were: uniform on the logarithm of K, ranging from 0.5 to 20 million lb dw; lognormal for r with mean=0.06 and SD in the logarithm of r =0.20; and lognormal for $P_{72}$ with mean=1.0 and SD in the logarithm of $P_{72}$=0.2. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 31.** Posterior means and summary statistics for several population parameters and management quantities for the **small coastal shark aggregate**. Results shown are for the base-case and alternative scenarios for the Bayesian LRSG using the Gibbs sampler. Values of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$ are millions of lb dw.

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Base-case | | 106.1 (19) [b] [68.3-145.2] [c] | 0.57 (33) [0.23-0.88] | 0.82 (10) [0.63-0.94] | 7.0 (62) [0.8-17.5] | 32.3 (38) [13.7-60.5] | 77.1 (15) [55.8-102.3] | 0.74 (18) [0.50-1.03] |
| Scenario 1 | 9 series scaled | 65.9 (44) [25.3-132.5] | 0.61 (30) [0.26-0.89] | 0.78 (12) [0.61-0.93] | 5.4 (63) [1.0-14.7] | 19.4 (61) [5.0-49.6] | 44.2 (52) [14.0-97.3] | 0.66 (20) [0.41-0.93] |
| Scenario 2 | 8 series (excluding Oregon II) | 104.7 (20) [66.6-145.2] | 0.57 (33) [0.24-0.88] | 0.81 (11) [0.62-0.94] | 7.3 (63) [0.9-18.5] | 32.0 (39) [13.5-59.9] | 79.8 (17) [56.9-109.9] | 0.78 (18) [0.52-1.07] |
| Scenario 3 | 8 series (excluding SC LL) | 65.8 (25) [41.9-108.4] | 0.60 (31) [0.25-0.88] | 0.80 (11) [0.62-0.94] | 4.9 (52) [0.9-10.8] | 19.4 (44) [8.1-40.9] | 42.2 (18) [30.9-61.1] | 0.67 (21) [0.40-0.94] |
| Scenario 4 | 8 series (excluding Recreational) | 113.4 (17) [76.4-146.8] | 0.57 (33) [0.23-0.88] | 0.82 (10) [0.63-0.94] | 7.6 (64) [0.8-19.5] | 34.5 (36) [15.3-61.9] | 84.2 (15) [63.3-112.6] | 0.76 (18) [0.52-1.03] |
| Scenario 5 | 8 series (excluding NMFS LL PC) | 107.6 (19) [70.0-145.8] | 0.57 (33) [0.23-0.88] | 0.82 (10) [0.63-0.94] | 7.0 (62) [0.8-17.7] | 32.9 (38) [14.1-61.1] | 78.1 (15) [57.2-103.3] | 0.74 (18) [0.50-1.03] |
| Scenario 6 | 8 series (excluding NMFS GN PC) | 106.6 (19) [69.2-145.4] | 0.57 (33) [0.24-0.88] | 0.82 (10) [0.63-0.94] | 6.9 (62) [0.8-17.4] | 32.5 (38) [13.9-60.2] | 78.6 (15) [57.5-103.7] | 0.76 (19) [0.51-1.05] |
| Scenario 7 | 8 series (excluding DGNOP) | 107.4 (19) [70.5-145.8] | 0.57 (34) [0.23-0.88] | 0.81 (11) [0.63-0.94] | 7.1 (63) [0.8-17.9] | 33.2 (38) [14.2-61.3] | 77.7 (15) [57.5-102.6] | 0.74 (18) [0.50-1.02] |
| Scenario 8 | 8 series (excluding SEAMAP) | 101.0 (21) [62.7-143.9] | 0.59 (32) [0.24-0.88] | 0.82 (11) [0.63-0.94] | 7.1 (62) [0.8-17.7] | 30.1 (40) [12.7-58.4] | 74.1 (16) [53.6-99.9] | 0.76 (20) [0.49-1.07] |
| Scenario 9 | 8 series (excluding VIMS LL) | 105.3 (20) [65.0-145.2] | 0.58 (32) [0.24-0.88] | 0.83 (10) [0.64-0.94] | 6.6 (61) [0.9-16.5] | 31.6 (39) [13.3-59.7] | 74.7 (16) [51.3-99.2] | 0.73 (19) [0.48-1.02] |

**Table 31.** (continued)

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Scenario 10 | 8 series (excluding NEFSC Bt. Tr.) | 103.2 (20) [67.1-144.0] | 0.59 (32) [0.24-0.89] | 0.80 (12) [0.62-0.94] | 8.2 (62) [0.9-20.3] | 30.6 (39) [13.3-58.2] | 81.0 (17) [58.8-113.2] | 0.80 (17) [0.54-1.08] |
| Scenario 11 | Range of prior on log of $B_0$=5-60 mil. | 54.8 (8) [43.0-59.8] | 0.59 (33) [0.23-0.88] | 0.79 (11) [0.62-0.94] | 4.8 (65) [0.4-11.9] | 16.3 (31) [8.3-26.6] | 56.5 (19) [37.0-78.9] | 1.03 (20) [0.70-1.50] |
| Scenario 12 | Range of prior on s=0.40-0.75 | 96.3 (19) [65.2-136.9] | 0.54 (36) [0.23-0.88] | 0.66 (12) [0.46-0.75] | 11.4 (54) [1.5-24.8] | 31.3 (39) [12.9-59.9] | 77.7 (15) [56.6-103.8] | 0.82 (14) [0.56-1.04] |
| Scenario 13 | Range of prior on z=0.20-0.60 | 108.1 (19) [b] [68.7-146.0] [c] | 0.42 (26) [0.22-0.59] | 0.81 (11) [0.63-0.94] | 4.8 (61) [0.5-11.8] | 40.5 (26) [23.3-63.6] | 76.1 (15) [55.5-100.5] | 0.72 (19) [0.49-1.02] |
| Scenario 14 | Range of prior on z=0.20-0.40 | 111.2 (19) [70.0-147.0] | 0.31 (18) [0.21-0.40] | 0.81 (11) [0.62-0.94] | 3.0 (65) [0.2-7.5] | 47.6 (21) [29.0-67.2] | 75.3 (15) [55.0-99.4] | 0.70 (20) [0.47-1.01] |
| Scenario 15 | $T_{lag}$=5 | 105.4 (19) [68.4-144.8] | 0.59 (32) [0.24-0.88] | 0.83 (10) [0.64-0.94] | 7.0 (62) [0.8-17.6] | 31.3 (38) [13.6-59.3] | 76.1 (15) [55.4-100.8] | 0.74 (18) [0.50-1.02] |
| Scenario 16 | Recruitment index added (NMFS GN PC) | 106.2 (19) [68.2-145.3] | 0.57 (34) [0.23-0.88] | 0.83 (10) [0.63-0.94] | 6.7 (63) [0.8-17.1] | 32.6 (38) [13.8-60.4] | 76.7 (15) [55.5-101.5] | 0.74 (19) [0.50-1.03] |
| Scenario 17 | SA bycatch in all missing years = mean for available years | 109.1 (18) [70.8-145.9] | 0.58 (33) [0.24-0.88] | 0.82 (10) [0.63-0.94] | 7.2 (59) [1.0-17.5] | 33.1 (37) [14.4-60.7] | 75.9 (15) [54.3-100.6] | 0.71 (18) [0.48-0.98] |
| Scenario 18 | No SA bycatch | 106.1 (19) [68.1-145.2] | 0.57 (34) [0.23-0.88] | 0.83 (10) [0.63-0.94] | 6.6 (65) [0.7-17.3] | 32.6 (38) [13.8-60.8] | 77.0 (15) [56.2-102.1] | 0.74 (19) [0.50-1.03] |

[a] The priors for the base-case scenario were: uniform on the logarithm of $B_0$, ranging from 5 to 150 million lb dw; uniform for z (range: 0.2-0.9); uniform for s (range: 0.60-0.95); and $T_{lag}$ was fixed at 4 yr. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 32.** Posterior means and summary statistics for several population parameters and management quantities for the **Atlantic sharpnose shark**. Results shown are for the base-case and alternative scenarios for the Bayesian LRSG using the Gibbs sampler. Values of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$ are millions of lb dw.

| **Scenario** | **Description of priors** [a] | **$B_0$** | **z** | **s** | **MSY** | **$B_{MSY}$** | **$B_{2001}$** | **$B_{2001}$/K** |
|---|---|---|---|---|---|---|---|---|
| Base-case | | 80.7 (12) [b]<br>[60.1-98.3] [c] | 0.61 (29)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 7.8 (51)<br>[1.8-17.0] | 23.0 (34)<br>[11.1-40.0] | 72.7 (13)<br>[54.6-92.0] | 0.91 (10)<br>[0.73-1.08] |
| Scenario 1 | 13 series scaled | 37.3 (42)<br>[16.7-79.7] | 0.68 (22)<br>[0.35-0.89] | 0.71 (11)<br>[0.60-0.87] | 4.8 (43)<br>[2.1-10.2] | 9.7 (61)<br>[3.0-26.0] | 30.1 (49)<br>[11.4-71.1] | 0.79 (12)<br>[0.60-0.97] |
| Scenario 2 | 12 series excluding Oregon II) | 79.3 (13)<br>[60.2-97.8] | 0.62 (28)<br>[0.28-0.89] | 0.75 (11)<br>[0.61-0.89] | 8.6 (49)<br>[2.0-18.1] | 22.3 (34)<br>[10.9-39.0] | 73.6 (13)<br>[56.8-93.9] | 0.93 (9)<br>[0.76-1.10] |
| Scenario 3 | 12 series excluding SC LL) | 46.0 (17)<br>[34.6-64.4] | 0.65 (25)<br>[0.32-0.89] | 0.75 (11)<br>[0.61-0.89] | 4.9 (40)<br>[1.8-9.4] | 12.4 (36)<br>[6.1-23.2] | 37.4 (16)<br>[28.3-52.6] | 0.82 (12)<br>[0.63-1.00] |
| Scenario 4 | 12 series excluding NMFS LL NE) | 81.8 (12)<br>[61.9-98.65] | 0.61 (29)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 7.8 (51)<br>[1.8-17.2] | 23.4 (33)<br>[11.4-40.1] | 74.1 (13)<br>[56.9-94.0] | 0.91 (10)<br>[0.74-1.08] |
| Scenario 5 | 12 series excluding Recreational) | 85.7 (10)<br>[67.1-99.2] | 0.61 (29)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 8.2 (53)<br>[1.7-18.5] | 24.6 (33)<br>[12.3-41.6] | 77.7 (12)<br>[61.1-97.5] | 0.91 (9)<br>[0.74-1.08] |
| Scenario 6 | 12 series excluding NMFS LL SEA) | 81.5 (12)<br>[61.3-98.5] | 0.61 (29)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 7.8 (51)<br>[1.7-17.2] | 23.3 (33)<br>[11.4-40.3] | 73.1 (13)<br>[55.9-93.1] | 0.90 (10)<br>[0.73-1.07] |
| Scenario 7 | 12 series excluding NMFS LL SEE) | 81.8 (12)<br>[62.4-98.5] | 0.61 (29)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 7.8 (51)<br>[1.7-17.2] | 23.4 (33)<br>[11.4-40.1] | 73.6 (13)<br>[56.8-93.5] | 0.90 (10)<br>[0.73-1.08] |
| Scenario 8 | 12 series excluding NMFS LL SEW) | 81.8 (12)<br>[62.3-98.6] | 0.61 (30)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 7.9 (52)<br>[1.7-17.4] | 23.5 (34)<br>[11.4-40.8] | 73.0 (12)<br>[57.0-92.4] | 0.90 (10)<br>[0.72-1.07] |
| Scenario 9 | 12 series excluding NMFS LL PC) | 81.5 (12)<br>[61.2-98.6] | 0.61 (30)<br>[0.27-0.89] | 0.77 (11)<br>[0.61-0.89] | 7.8 (52)<br>[1.7-17.3] | 23.4 (34)<br>[11.3-40.7] | 72.8 (13)<br>[55.2-92.8] | 0.90 (9)<br>[0.73-1.06] |

**Table 32.** (continued)

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Scenario 10 | 12 series excluding NMFS GN PC) | 80.7 (12) [60.0-98.3] | 0.61 (29) [0.27-0.89] | 0.77 (11) [0.61-0.89] | 7.7 (51) [1.7-17.0] | 23.1 (34) [11.3-40.0] | 73.2 (13) [55.5-92.5] | 0.91 (10) [0.74-1.09] |
| Scenario 11 | 12 series excluding DGNOP) | 81.7 (12) [62.4-98.4] | 0.60 (30) [0.26-0.89] | 0.77 (11) [0.61-0.89] | 7.8 (51) [1.7-17.1] | 23.7 (33) [11.5-40.5] | 73.1 (12) [56.9-91.6] | 0.89 (9) [0.73-1.06] |
| Scenario 12 | 12 series excluding SEAMAP) | 80.4 (12) [59.9-98.3] | 0.61 (29) [0.26-0.89] | 0.77 (11) [0.61-0.89] | 7.7 (52) [1.6-17.0] | 23.1 (34) [11.1-40.4] | 71.9 (12) [55.6-91.2] | 0.90 (10) [0.72-1.09] |
| Scenario 13 | 12 series excluding VIMS LL) | 81.0 (12) [61.8-98.3] | 0.61 (29) [0.27-0.89] | 0.77 (11) [0.61-0.89] | 7.9 (51) [1.8-17.3] | 23.1 (33) [11.4-40.0] | 73.2 (12) [57.0-92.1] | 0.91 (10) [0.73-1.08] |
| Scenario 14 | 12 series excluding NEFSC Bt. Tr.) | 81.9 (11) [64.3-98.4] | 0.61 (30) [0.26-0.89] | 0.76 (11) [0.61-0.89] | 8.0 (51) [1.7-17.6] | 23.7 (33) [11.6-40.8] | 72.8 (11) [57.9-90.8] | 0.89 (9) [0.73-1.04] |
| Scenario 15 | Range of prior on log of $B_0$=5-40 mil. | 38.0 (4) [33.7-39.9] | 0.69 (22) [0.35-0.89] | 0.69 (9) [0.60-0.84] | 5.9 (34) [1.7-9.7] | 9.4 (29) [5.6-15.4] | 35.7 (14) [29.0-49.5] | 0.94 (14) [0.78-1.31] |
| Scenario 16 | Range of prior on s=0.40-0.70 | 77.0 (13) [58.6-96.9] | 0.58 (32) [0.25-0.88] | 0.58 (14) [0.41-0.70] | 12.8 (48) [2.4-26.4] | 23.2 (35) [10.8-40.9] | 73.0 (13) [56.0-93.0] | 0.95 (7) [0.81-1.07] |
| Scenario 17 | Range of prior on z=0.20-0.60 | 82.5 (12) [62.9-98.7] | 0.44 (23) [0.24-0.59] | 0.76 (10) [0.61-0.89] | 5.3 (47) [1.1-10.9] | 29.8 (19) [20.3-42.7] | 72.6 (12) [56.2-91.1] | 0.88 (10) [0.71-1.07] |
| Scenario 18 | Range of prior on z=0.20-0.40 | 84.3 (11) [64.6-99.0] | 0.33 (15) [0.22-0.40] | 0.75 (11) [0.61-0.89] | 3.3 (48) [0.5-6.7] | 35.4 (14) [26.2-45.0] | 72.0 (12) [56.8-90.8] | 0.86 (11) [0.68-1.06] |
| Scenario 19 | $T_{lag}$=4 | 81.4 (12) [70.0-98.3] | 0.61 (30) [0.26-0.89] | 0.77 (11) [0.61-0.89] | 7.7 (52) [1.6-17.1] | 23.3 (34) [11.4-40.4] | 72.9 (12) [55.9-92.2] | 0.90 (10) [0.73-1.07] |
| Scenario 20 | Recruitment index added (NMFS GN PC) | 81.3 (12) [61.4-98.5] | 0.61 (29) [0.27-0.89] | 0.77 (10) [0.61-0.89] | 7.7 (51) [1.7-17.0] | 23.3 (33) [11.1-40.2] | 73.4 (13) [56.7-93.1] | 0.91 (10) [0.74-1.08] |

**Table 32.** (continued)

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Scenario 21 | SA bycatch in all missing years = mean for available years | 85.2 (10) [66.2-99.1] | 0.63 (27) [0.30-0.89] | 0.77 (10) [0.61-0.89] | 8.4 (45) [2.7-17.3] | 23.7 (32) [12.0-39.6] | 71.2 (12) [55.0-88.8] | 0.84 (10) [0.68-1.00] |
| Scenario 22 | No SA bycatch | 80.4 (12) [60.3-98.3] | 0.60 (30) [0.26-0.88] | 0.78 (10) [0.62-0.89] | 7.0 (54) [1.4-16.2] | 23.5 (34) [11.3-40.8] | 72.5 (13) [55.8-92.3] | 0.91 (10) [0.73-1.09] |

[a] The priors for the base-case scenario were: uniform on the logarithm of $B_0$, ranging from 5 to 100 million lb dw; uniform for z (range: 0.2-0.9); uniform for s (range: 0.60-0.90); and $T_{lag}$ was fixed at 3 yr. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 33.** Posterior means and summary statistics for several population parameters and management quantities for the **bonnethead**. Results shown are for the base-case and alternative scenarios for the Bayesian LRSG using the Gibbs sampler. Values of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$ are millions of lb dw.

| **Scenario** | **Description of priors** [a] | **$B_0$** | **z** | **s** | **MSY** | **$B_{MSY}$** | **$B_{2001}$** | **$B_{2001}$/K** |
|---|---|---|---|---|---|---|---|---|
| Base-case | | 15.0 (22) [b]<br>[10.2-23.7] [c] | 0.58 (33)<br>[0.23-0.88] | 0.68 (16)<br>[0.51-0.88] | 1.8 (61)<br>[0.2-4.3] | 4.6 (42)<br>[2.0-9.0] | 12.8 (24)<br>[8.6-21.1] | 0.86 (10)<br>[0.64-0.99] |
| Scenario 1 | 4 series scaled | 25.7 (35)<br>[6.5-39.3] | 0.55 (36)<br>[0.22-0.88] | 0.69 (16)<br>[0.51-0.89] | 2.9 (78)<br>[0.2-8.7] | 8.1 (17)<br>[1.7-16.6] | 23.3 (40)<br>[4.5-38.3] | 0.89 (12)<br>[0.61-1.04] |
| Scenario 2 | 3 series excluding Recreational) | 24.1 (30)<br>[13.3-38.6] | 0.56 (36)<br>[0.22-0.88] | 0.69 (17)<br>[0.51-0.89] | 2.8 (73)<br>[0.2-7.9] | 7.5 (44)<br>[2.8-15.4] | 21.8 (34)<br>[11.1-37.2] | 0.90 (10)<br>[0.69-1.04] |
| Scenario 3 | 3 series excluding NMFS GN PC) | 15.0 (20)<br>[10.5-22.4] | 0.58 (33)<br>[0.24-0.88] | 0.68 (16)<br>[0.51-0.88] | 1.9 (58)<br>[0.3-4.4] | 4.5 (39)<br>[2.0-8.7] | 13.0 (21)<br>[8.9-20.1] | 0.87 (10)<br>[0.67-1.00] |
| Scenario 4 | 3 series excluding DGNOP) | 15.6 (25)<br>[10.5-26.3] | 0.56 (36)<br>[0.22-0.88] | 0.69 (16)<br>[0.51-0.89] | 1.7 (67)<br>[0.1-4.4] | 4.9 (44)<br>[2.0-10.2] | 13.0 (28)<br>[8.2-23.2] | 0.84 (12)<br>[0.59-0.98] |
| Scenario 5 | 3 series excluding SEAMAP) | 1.7 (24)<br>[1.5-2.1] | 0.83 (7)<br>[0.67-0.90] | 0.54 (6)<br>[0.50-0.62] | 0.5 (7)<br>[0.4-0.6] | 0.3 (23)<br>[0.2-0.5] | 0.6 (19)<br>[0.3-0.8] | 0.33 (19)<br>[0.20-0.44] |
| Scenario 6 | Range of prior on log of $B_0$=1-20 mil. | 14.2 (16)<br>[10.1-19.2] | 0.58 (33)<br>[0.24-0.88] | 0.68 (16)<br>[0.51-0.88] | 1.7 (59)<br>[0.2-4.1] | 4.3 (36)<br>[1.9-7.8] | 12.1 (18)<br>[8.3-17.3] | 0.85 (10)<br>[0.64-0.99] |
| Scenario 7 | Range of prior on s=0.30-0.70 | 14.6 (24)<br>[9.7-24.7] | 0.57 (34)<br>[0.23-0.88] | 0.49 (23)<br>[0.31-0.69] | 2.8 (58)<br>[0.3-6.5] | 4.5 (43)<br>[1.9-9.1] | 13.2 (26)<br>[8.7-23.0] | 0.91 (7)<br>[0.75-0.99] |
| Scenario 8 | Range of prior on z-0.20-0.60 | 15.5 (24)<br>[10.7-25.0] | 0.42 (26)<br>[0.22-0.59] | 0.67 (16)<br>[0.51-0.88] | 1.2 (59)<br>[0.1-2.8] | 5.8 (31)<br>[3.5-10.3] | 12.9 (27)<br>[8.6-21.9] | 0.83 (11)<br>[0.61-0.98] |
| Scenario 9 | Range of prior on z=0.20-0.40 | 16.3 (22)<br>[10.9-24.8] | 0.31 (18)<br>[0.21-0.40] | 0.67 (16)<br>[0.51-0.88] | 0.7 (59)<br>[0.1-1.7] | 7.0 (24)<br>[4.4-11.2] | 12.9 (24)<br>[8.2-20.7] | 0.79 (13)<br>[0.57-0.96] |

**Table 33.** (continued)

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Scenario 10 | $T_{lag}$=4 | 16.0 (25) [10.5-26.0] | 0.56 (35) [0.23-0.88] | 0.68 (17) [0.51-0.88] | 1.9 (64) [0.2-4.7] | 5.0 (43) [2.0-9.9] | 13.8 (27) [8.8-23.7] | 0.86 (10) [0.65-1.00] |
| Scenario 11 | SA bycatch in all missing years = mean for available years | 15.6 (22) [10.7-23.9] | 0.57 (34) [0.23-0.88] | 0.68 (16) [0.51-0.88] | 1.9 (61) [0.2-4.5] | 4.8 (41) [2.0-9.4] | 13.2 (24) [8.8-21.3] | 0.85 (11) [0.62-0.98] |
| Scenario 12 | No SA bycatch | 15.2 (27) [9.8-25.3] | 0.57 (34) [0.23-0.88] | 0.68 (16) [0.51-0.88] | 1.8 (64) [0.2-4.4] | 4.7 (45) [1.9-9.5] | 13.0 (30) [8.0-23.1] | 0.85 (11) [0.62-0.98] |

[a] The priors for the base-case scenario were: uniform on the logarithm of $B_0$, ranging from 5 to 40 million lb dw; uniform for z (range: 0.2-0.9); uniform for s (range: 0.50-0.90); and $T_{lag}$ was fixed at 3 yr. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 34.** Posterior means and summary statistics for several population parameters and management quantities for the **blacknose shark**. Results shown are for the base-case and alternative scenarios for the Bayesian LRSG using the Gibbs sampler. Values of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$ are millions of lb dw.

| **Scenario** | **Description of priors** [a] | **$B_0$** | **z** | **s** | **MSY** | **$B_{MSY}$** | **$B_{2001}$** | **$B_{2001}/K$** |
|---|---|---|---|---|---|---|---|---|
| Base-case | | 10.5 (29) [b] [6.5-18.8] [c] | 0.55 (37) [0.22-0.88] | 0.79 (11) [0.66-0.94] | 0.80 (78) [0.04-1.1] | 3.3 (29) [1.3-6.7] | 10.4 (29) [6.5-18.7] | 0.99 (11) [0.82-1.26] |
| Scenario 1 | 7 series scaled | 12.5 (54) [2.5-24.2] | 0.55 (37) [0.22-0.88] | 0.79 (11) [0.66-0.94] | 0.95 (95) [0.04-3.5] | 3.9 (64) [0.7-9.8] | 12.4 (57) [2.0-25.8] | 0.97 (13) [0.74-1.25] |
| Scenario 2 | 7 series excluding SC LL) | 2.0 (44) [0.91-4.2] | 0.58 (34) [0.22-0.88] | 0.75 (10) [0.65-0.93] | 0.19 (71) [0.01-0.5] | 0.6 (56) [0.2-1.5] | 1.6 (58) [0.5-3.9] | 0.74 (21) [0.46-1.07] |
| Scenario 3 | 7 series excluding Recreational) | 13.8 (29) [7.9-23.2] | 0.55 (36) [0.22-0.88] | 0.79 (11) [0.66-0.94] | 1.06 (78) [0.05-3.1] | 4.3 (43) [1.7-8.9] | 13.7 (31) [7.7-23.5] | 0.99 (11) [0.81-1.23] |
| Scenario 4 | 7 series excluding NMFS LL SEE) | 10.6 (28) [6.6-18.1] | 0.55 (37) [0.22-0.88] | 0.79 (11) [0.66-0.94] | 0.81 (77) [0.04-2.3] | 3.3 (42) [1.4-6.7] | 10.3 (28) [6.5-17.8] | 0.97 (10) [0.80-1.29] |
| Scenario 5 | 7 series excluding NMFS LL SEW) | 11.1 (29) [6.6-19.3] | 0.55 (37) [0.22-0.88] | 0.79 (11) [0.66-0.94] | 0.84 (78) [0.04-2.5] | 3.5 (43) [1.4-7.2] | 10.8 (30) [6.5-19.1] | 0.98 (10) [0.80-1.22] |
| Scenario 6 | 7 series excluding NMFS LL PC) | 12.1 (34) [6.9-22.6] | 0.55 (37) [0.22-0.88] | 0.80 (11) [0.66-0.94] | 0.91 (81) [0.05-2.8] | 3.8 (47) [1.4-8.4] | 12.0 (35) [7.0-22.8] | 0.99 (11) [0.82-1.26] |
| Scenario 7 | 7 series excluding NMFS GN PC) | 10.6 (25) [6.8-17.0] | 0.55 (36) [0.22-0.88] | 0.79 (11) [0.66-0.94] | 0.81 (75) [0.04-2.3] | 3.3 (40) [1.4-6.4] | 10.6 (25) [6.9-17.1] | 1.00(11) [0.82-1.27] |
| Scenario 8 | 7 series excluding DGNOP) | 11.1 (31) [6.5-20.0] | 0.55 (37) [0.22-0.88] | 0.80 (11) [0.66-0.94] | 0.84 (79) [0.04-2.5] | 3.5 (45) [1.4-7.4] | 10.9 (31) [6.5-19.8] | 0.98 (11) [0.80-1.23] |
| Scenario 9 | Range of prior on log of $B_0$=0.5-40 | 10.5 (24) [6.7-16.8] | 0.55 (37) [0.22-0.88] | 0.80 (11) [0.66-0.94] | 0.80 (75) [0.04-2.2] | 3.3 (39) [1.4-6.2] | 10.3 (24) [6.8-16.6] | 0.99 (11) [0.81-1.24] |

**Table 34.** (continued)

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Scenario 10 | Range of prior on log of $B_0$=0.5-60 | 10.5 (24) [6.7-16.8] | 0.55 (37) [0.22-0.88] | 0.80 (11) [0.66-0.94] | 0.80 (75) [0.04-2.2] | 3.3 (39) [1.4-6.2] | 10.3 (24) [6.8-16.6] | 0.99 (11) [0.81-1.24] |
| Scenario 11 | Range of prior on s=0.45-0.75 | 10.7 (26) [7.1-17.6] | 0.55 (36) [0.22-0.88] | 0.60 (15) [0.46-0.74] | 1.61 (64) [0.10-4.0] | 3.4 (41) [1.4-6.7] | 10.5 (27) [6.9-17.5] | 0.98 (6) [0.88-1.11] |
| Scenario 12 | Range of prior on z-0.20-0.60 | 10.7 (27) [6.6-17.5] | 0.40 (29) [0.21-0.59] | 0.80 (11) [0.66-0.94] | 0.51 (76) [0.02-1.4] | 4.1 (31) [2.3-7.2] | 10.5 (27) [6.7-17.4] | 0.99 (12) [0.80-1.26] |
| Scenario 13 | Range of prior on z=0.20-0.40 | 10.7 (28) [6.6-18.8] | 0.30 (19) [0.21-0.40] | 0.80 (11) [0.66-0.94] | 0.28 (79) [0.01-0.8] | 4.6 (29) [2.8-8.2] | 10.6 (29) [6.8-19.1] | 1.00 (13) [0.80-1.31] |
| Scenario 14 | $T_{lag}$=5 | 10.4 (29) [6.3-18.3] | 0.55 (37) [0.22-0.88] | 0.80 (11) [0.66-0.94] | 0.79 (79) [0.04-2.3] | 3.3 (43) [1.3-6.7] | 10.3 (29) [6.4-18.6] | 1.00 (11) [0.82-1.26] |
| Scenario 15 | Catch in 1984, 1985, 1990, 1991=mean catch (1983-1994) | 10.4 (27) [6.4-17.9] | 0.55 (36) [0.22-0.88] | 0.80 (11) [0.66-0.94] | 0.79 (77) [0.04-2.3] | 3.3 (42) [1.4-6.5] | 10.2 (27) [6.5-17.5] | 0.99 (11) [0.82-1.25] |

[a] The priors for the base-case scenario were: uniform on the logarithm of $B_0$, ranging from 0.5 to 25 million lb dw; uniform for z (range: 0.2-0.9); uniform for s (range: 0.65-0.95); and $T_{lag}$ was fixed at 4 yr. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Table 35.** Posterior means and summary statistics for several population parameters and management quantities for the **finetooth shark**. Results shown are for the base-case and alternative scenarios for the Bayesian LRSG using the Gibbs sampler. Values of $B_0$, MSY, $B_{MSY}$, and $B_{2001}$ are millions of lb dw.

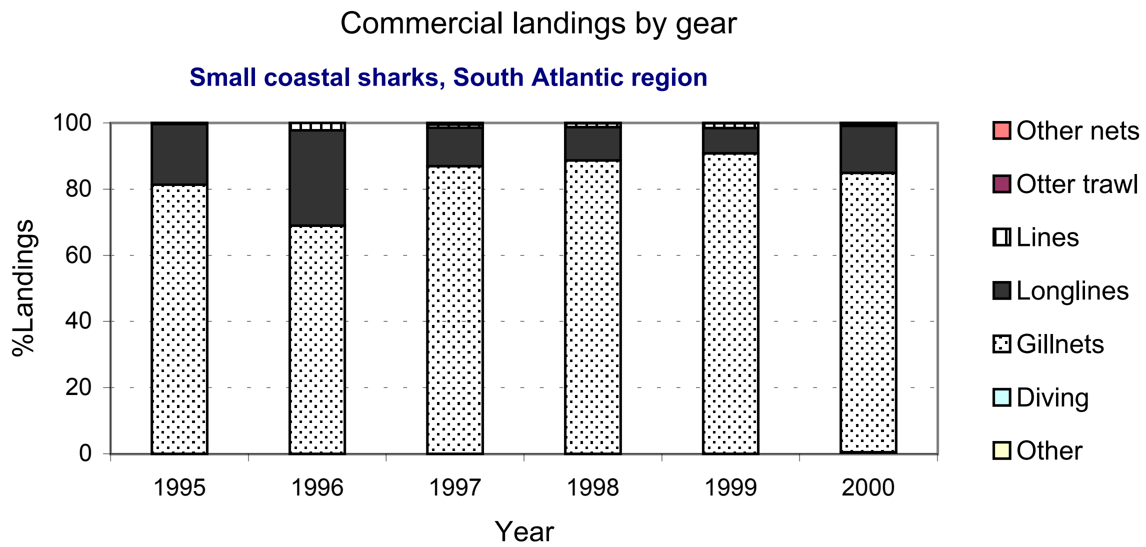
| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Base-case | | 2.6 (66) [b] [0.9-7.8] [c] | 0.57 (35) [0.22-0.88] | 0.73 (12) [0.60-0.89] | 0.26 (93) [0.016-0.9] | 0.8 (77) [0.22-2.6] | 1.9 (89) [0.3-7.3] | 0.68 (23) [0.33-0.97] |
| Scenario 1 | 5 series scaled | 11.6 (43) [3.0-19.6] | 0.55 (37) [0.22-0.88] | 0.75 (11) [0.61-0.89] | 1.08 (82) [0.052-3.3] | 3.6 (54) [0.76-8.0] | 11.1 (47) [2.4-20.1] | 0.95 (10) [0.75-1.15] |
| Scenario 2 | 5 series excluding Recreational) | 6.9 (52) [1.9-15.3] | 0.56 (36) [0.22-0.88] | 0.75 (11) [0.61-0.89] | 0.65 (87) [0.032-2.2] | 2.2 (63) [0.46-5.6] | 6.3 (58) [1.2-14.8] | 0.88 (12) [0.63-1.08] |
| Scenario 3 | 5 series excluding NMFS LL SEW) | 3.3 (63) [1.1-9.2] | 0.56 (35) [0.22-0.88] | 0.73 (12) [0.60-0.89] | 0.33 (93) [0.018-1.2] | 1.0 (73) [0.25-3.2] | 2.7 (79) [0.4-8.6] | 0.74 (21) [0.39-1.00] |
| Scenario 4 | 5 series excluding NMFS LL PC) | 4.4 (83) [1.2-15.1] | 0.56 (36) [0.22-0.88] | 0.73 (12) [0.60-0.89] | 0.42 (111) [0.022-1.8] | 1.4 (94) [0.27-5.1] | 3.8 (97) [0.6-14.6] | 0.79 (20) [0.46-1.06] |
| Scenario 5 | 5 series excluding NMFS GN PC) | 2.9 (61) [1.0-7.2] | 0.57 (35) [0.22-0.88] | 0.73 (12) [0.60-0.89] | 0.29 (90) [0.018-1.0] | 0.9 (72) [0.23-0.2] | 2.3 (79) [0.4-6.6] | 0.72 (23) [0.36-1.00] |
| Scenario 6 | 5 series excluding DGNOP) | 0.95 (24) [0.69-1.5] | 0.56 (35) [0.22-0.88] | 0.72 (12) [0.60-0.89] | 0.10 (60) [0.001-0.2] | 0.3 (41) [0.13-0.6] | 0.3 (75) [0.1-0.8] | 0.27 (48) [0.06-0.55] |
| Scenario 7 | Range of prior on log of $B_0$=0.5-40 | 3.1 (72) [1.0-9.9] | 0.56 (36) [0.22-0.88] | 0.73 (12) [0.61-0.89] | 0.31 (100) [0.018-1.2] | 1.0 (84) [0.23-3.4] | 2.5 (92) [0.4-9.4] | 0.72 (23) [0.35-1.00] |
| Scenario 8 | Range of prior on log of $B_0$=0.5-60 | 3.1 (72) [1.0-9.9] | 0.56 (36) [0.22-0.88] | 0.73 (12) [0.60-0.89] | 0.31 (100) [0.018-1.2] | 1.0 (84) [0.23-3.4] | 2.5 (92) [0.4-9.4] | 0.72 (23) [0.35-1.00] |
| Scenario 9 | Range of prior on s=0.40-0.70 | 1.9 (51) [0.80-4.6] | 0.57 (35) [0.22-0.88] | 0.53 (16) [0.41-0.69] | 0.34 (75) [0.026-1.0] | 0.6 (19) [0.17-1.6] | 1.4 (68) [0.3-4.2] | 0.70 (19) [0.41-0.92] |

**Table 35.** (continued)

| Scenario | Description of priors [a] | $B_0$ | z | s | MSY | $B_{MSY}$ | $B_{2001}$ | $B_{2001}/K$ |
|---|---|---|---|---|---|---|---|---|
| Scenario 10 | Range of prior on z-0.20-0.60 | 2.7 (74) [0.99-9.1] | 0.41 (28) [0.21-0.59] | 0.73 (12) [0.60-0.89] | 0.17 (100) [0.010-0.6] | 1.0 (77) [0.34-3.5] | 2.1 (97) [0.4-8.5] | 0.68 (25) [0.34-0.98] |
| Scenario 11 | Range of prior on z=0.20-0.40 | 2.6 (55) [1.0-6.6] | 0.30 (19) [0.21-0.40] | 0.73 (12) [0.61-0.89] | 0.090 (86) [0.005-0.3] | 1.1 (55) [0.43-2.9] | 1.9 (74) [0.4-1.0] | 0.68 (24) [0.34-0.97] |
| Scenario 12 | $T_{lag}$=5 | 2.6 (54) [0.95-6.6] | 0.56 (36) [0.22-0.88] | 0.73 (12) [0.60-0.89] | 0.26 (84) [0.016-0.8] | 0.8 (66) [0.22-2.3] | 2.0 (72) [0.3-6.0] | 0.70 (23) [0.33-0.96] |
| Scenario 13 | Catch in 1990=mean catch (1986-1994) | 2.2 (48) [0.92-5.0] | 0.57 (35) [0.22-0.88] | 0.72 (12) [0.60-0.89] | 0.23 (77) [0.016-0.7] | 0.7 (60) [0.20-1.8] | 1.6 (67) [0.3-4.5] | 0.66 (25) [0.31-0.93] |

[a] The priors for the base-case scenario were: uniform on the logarithm of $B_0$, ranging from 0.5 to 20 million lb dw; uniform for z (range: 0.2-0.9); uniform for s (range: 0.60-0.99); and $T_{lag}$ was fixed at 4 yr. All scenarios are the same as the base-case, except for the changes described for each.
[b] Values in parentheses are coefficients of variation expressed as a percentage.
[c] Values in brackets are the 2.5th and 97.5th percentiles.

**Figure 1.** Commercial landings of small coastal sharks by region and gear type




| Region=SA Gear | %landings (all years combined) |
|---|---|
| Other | 0.083 |
| Diving | 0.008 |
| Gillnets | 83.525 |
| Longlines | 15.115 |
| Lines | 1.137 |
| Otter trawl | 0.114 |
| Pots & traps | 0.001 |
| Other nets | 0.018 |

| | %landings | | |
|---|---|---|---|
| Year | SA | GOM | UNK |
| 1995 | 68.60 | 29.57 | 1.84 |
| 1996 | 57.15 | 7.42 | 35.43 |
| 1997 | 97.13 | 2.87 | 0.00 |
| 1998 | 91.85 | 3.01 | 5.14 |
| 1999 | 87.45 | 2.94 | 9.62 |
| 2000 | 96.69 | 3.31 | 0.00 |

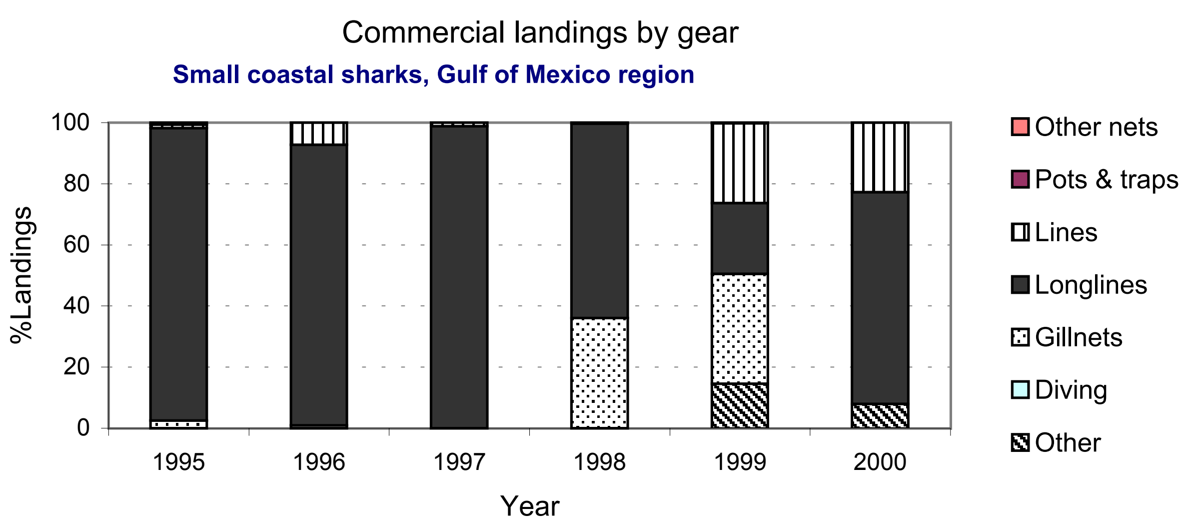
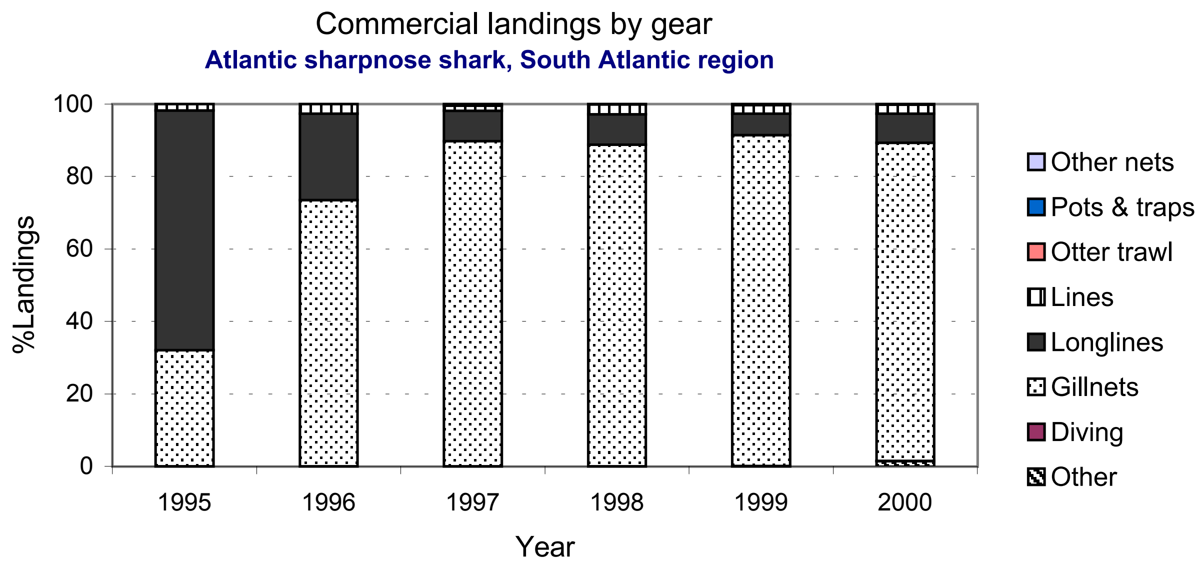


**Figure 2.** Commercial landings of Atlantic sharpnose shark by region and gear type.




| Region=SA Gear | %landings (all years combined) |
|---|---|
| Other | 0.23 |
| Diving | 0.02 |
| Gillnets | 77.20 |
| Longlines | 20.14 |
| Lines | 2.22 |
| Otter trawl | 0.15 |
| Pots & traps | 0.00 |
| Other nets | 0.03 |

| | %landings | | |
|---|---|---|---|
| Year | SA | GOM | UNK |
| 1995 | 96.70 | 3.30 | 0.00 |
| 1996 | 98.26 | 0.00 | 1.74 |
| 1997 | 99.79 | 0.21 | 0.00 |
| 1998 | 97.96 | 0.84 | 1.20 |
| 1999 | 97.21 | 0.87 | 1.93 |
| 2000 | 97.94 | 2.06 | 0.00 |

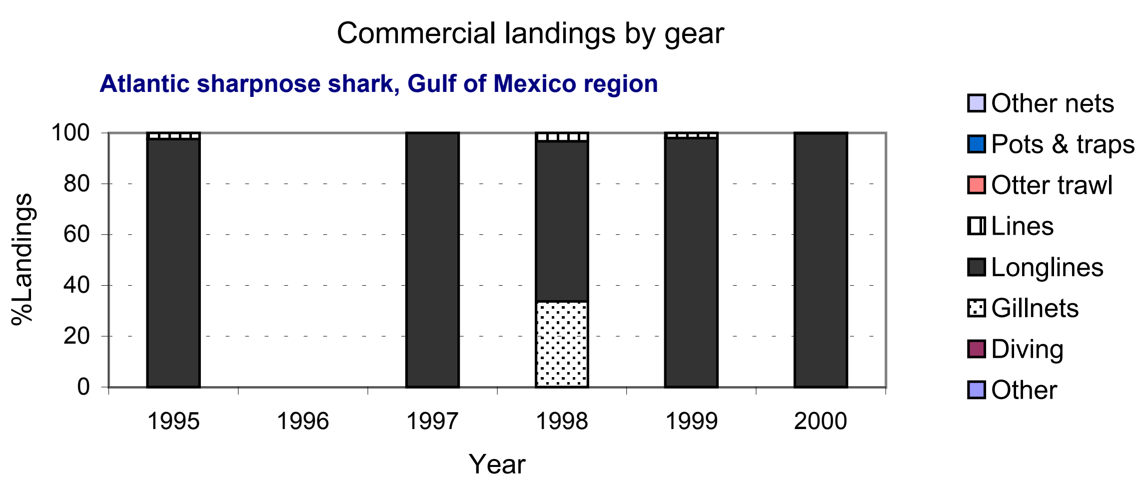
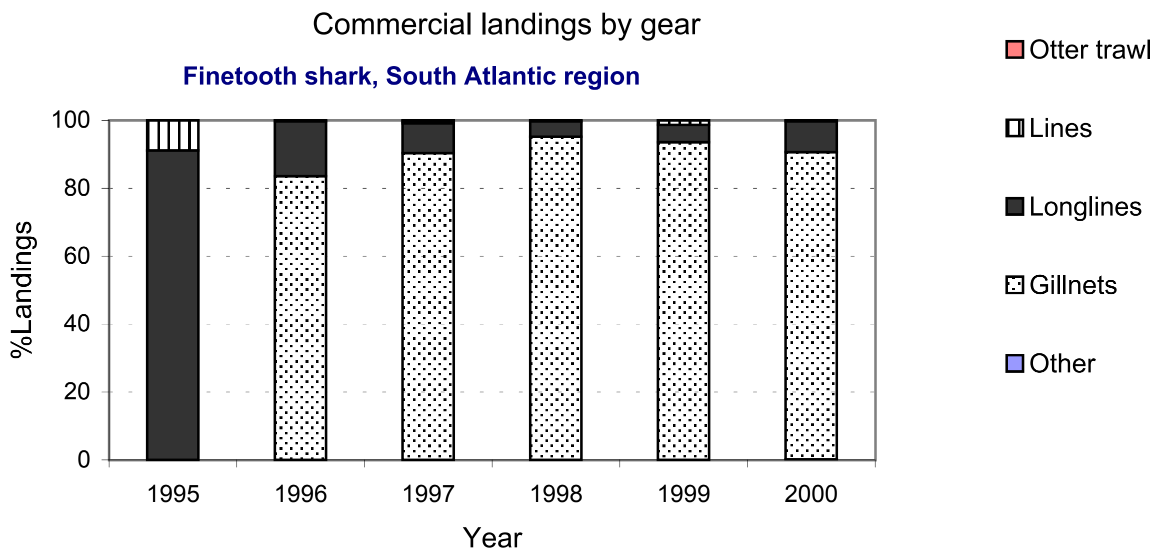


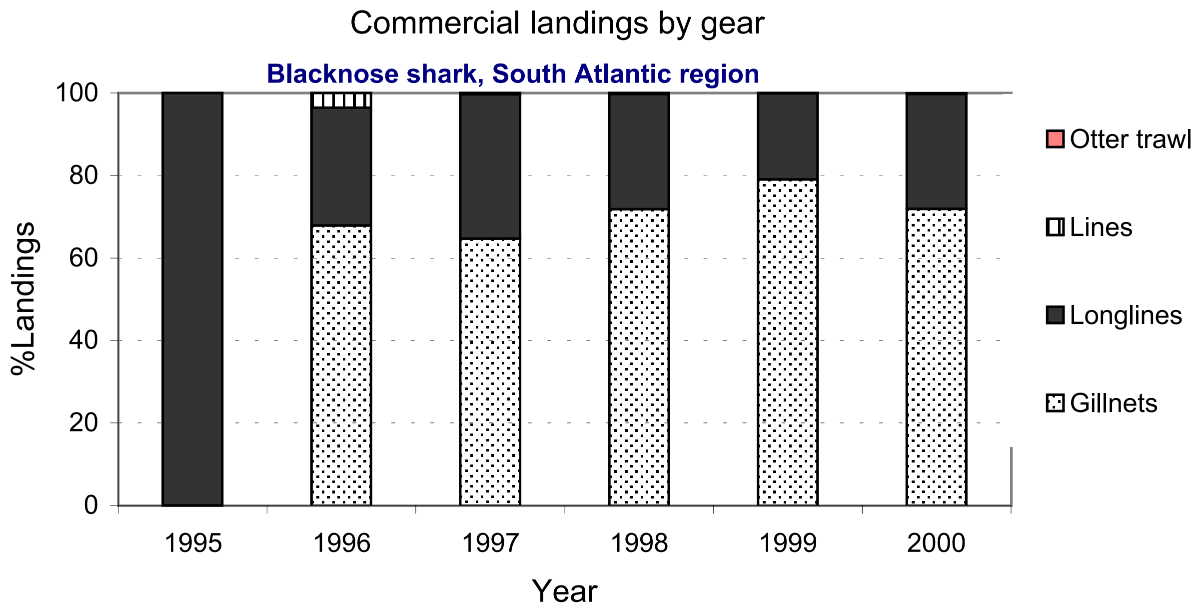
**Figure 3.** Commercial landings of finetooth shark by region and gear type.




| Region=SA<br>Gear | %landings<br>(all years combined) |
|---|---|
| Other | 0.03 |
| Diving | 0.00 |
| Gillnets | 75.54 |
| Longlines | 22.45 |
| Lines | 1.93 |
| Otter trawl | 0.06 |
| Pots & traps | 0.00 |
| Other nets | 0.00 |

| | | %landings | |
|---|---|---|---|
| Year | SA | GOM | UNK |
| 1995 | 100.00 | 0.00 | 0.00 |
| 1996 | 33.43 | 1.70 | 64.87 |
| 1997 | 99.22 | 0.78 | 0.00 |
| 1998 | 95.93 | 0.18 | 3.89 |
| 1999 | 87.48 | 1.31 | 11.21 |
| 2000 | 99.99 | 0.01 | 0.00 |

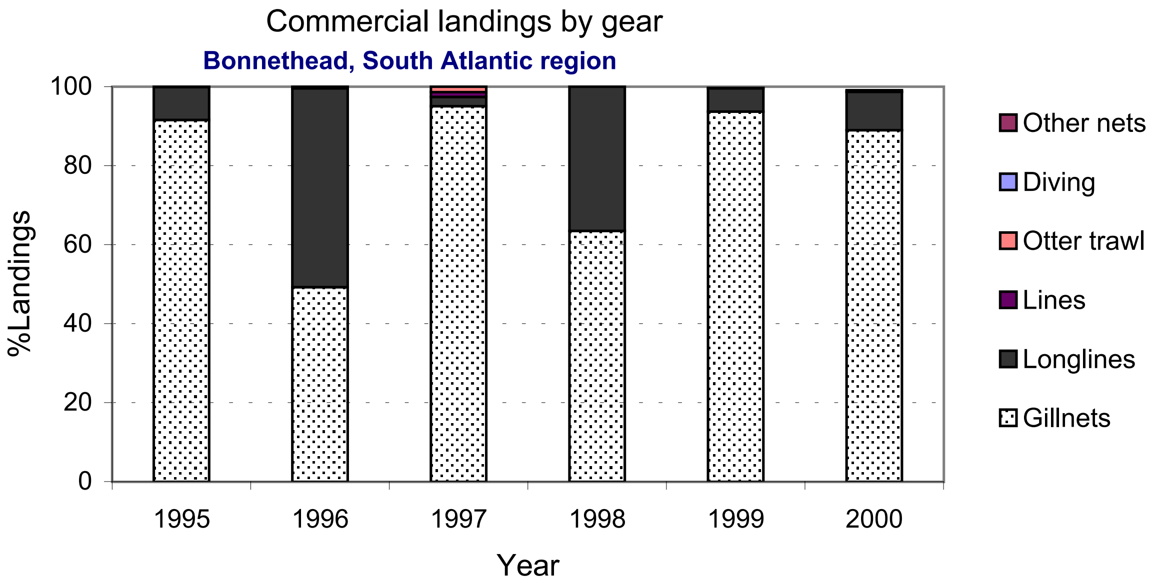
**Figure 4.** Commercial landings of blacknose shark by region and gear type.




| Region=SA Gear | %landings (all years combined) |
|---|---|
| Other | 0.01 |
| Diving | 0.00 |
| Gillnets | 59.23 |
| Longlines | 40.03 |
| Lines | 0.70 |
| Otter trawl | 0.03 |
| Pots & traps | 0.00 |
| Other nets | 0.00 |

| | %landings | | |
|---|---|---|---|
| Year | SA | GOM | UNK |
| 1995 | 27.59 | 65.33 | 7.08 |
| 1996 | 48.15 | 10.51 | 41.35 |
| 1997 | 84.52 | 15.48 | 0.00 |
| 1998 | 70.75 | 14.04 | 15.21 |
| 1999 | 71.48 | 9.93 | 18.59 |
| 2000 | 90.74 | 9.26 | 0.00 |

**Figure 5.** Commercial landings of bonnetehad by region and gear type




| Region=SA<br>Gear | %landings<br>(all years combined) |
|---|---|
| Other | 0.170 |
| Diving | 0.001 |
| Gillnets | 80.353 |
| Longlines | 18.841 |
| Lines | 0.348 |
| Otter trawl | 0.244 |
| Pots & traps | 0.000 |
| Other nets | 0.044 |

| | | %landings | |
|---|---|---|---|
| Year | SA | GOM | UNK |
| 1995 | 76.54 | 22.74 | 0.72 |
| 1996 | 54.60 | 17.36 | 28.04 |
| 1997 | 99.89 | 0.11 | 0.00 |
| 1998 | 89.67 | 1.02 | 9.32 |
| 1999 | 78.02 | 7.31 | 14.67 |
| 2000 | 99.90 | 0.10 | 0.00 |

**Figure 6.** Recreational catches of small coastal sharks by region

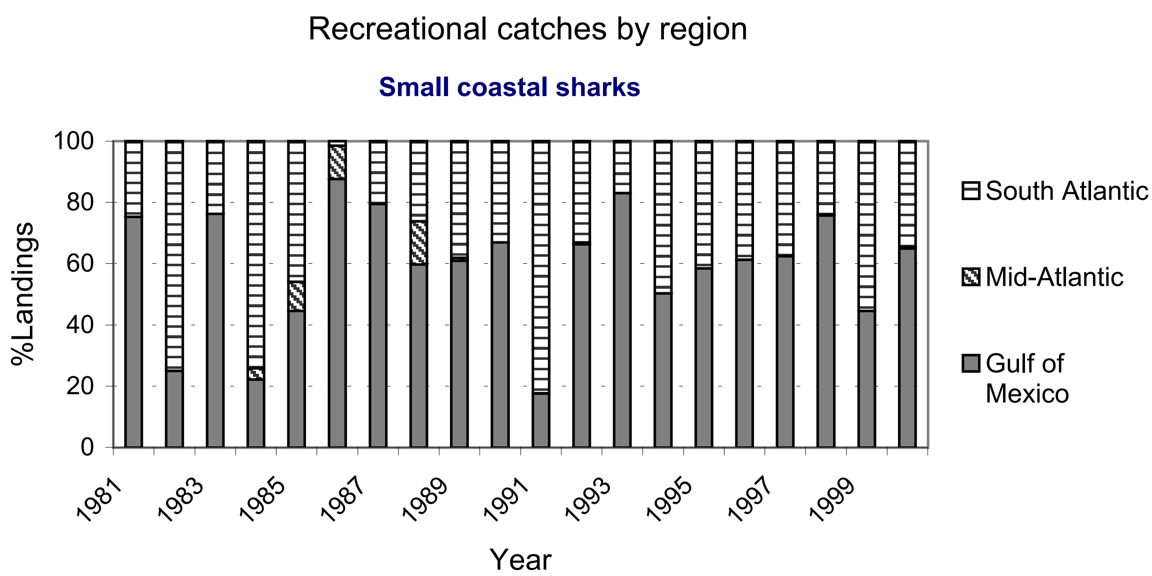



**Figure 7.** Recreational catches of Atlantic sharpnose shark by region

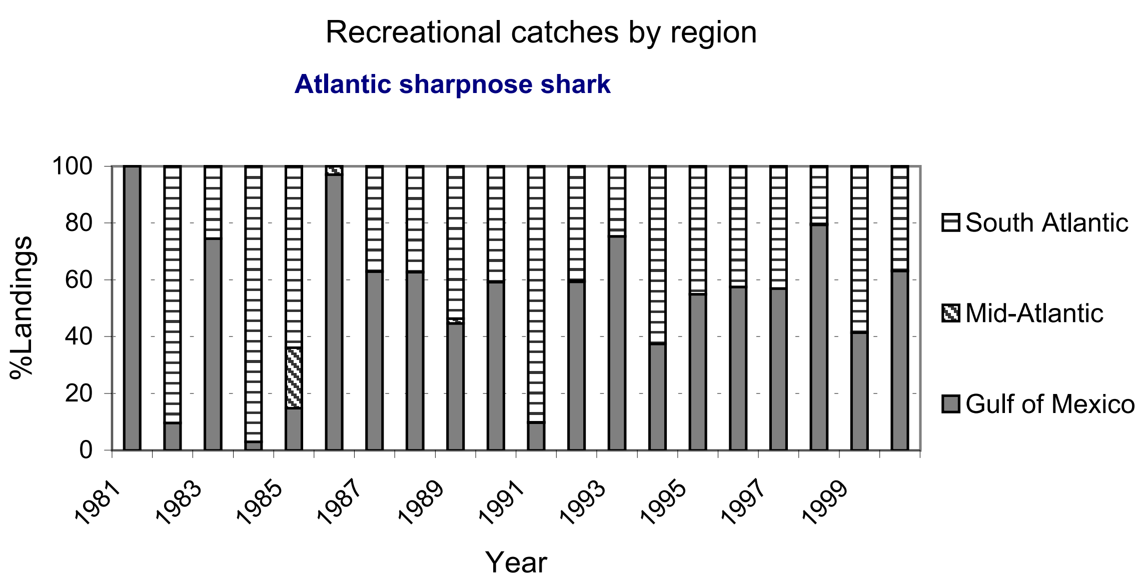


**Figure 8.** Recreational catches of blacknose shark by region

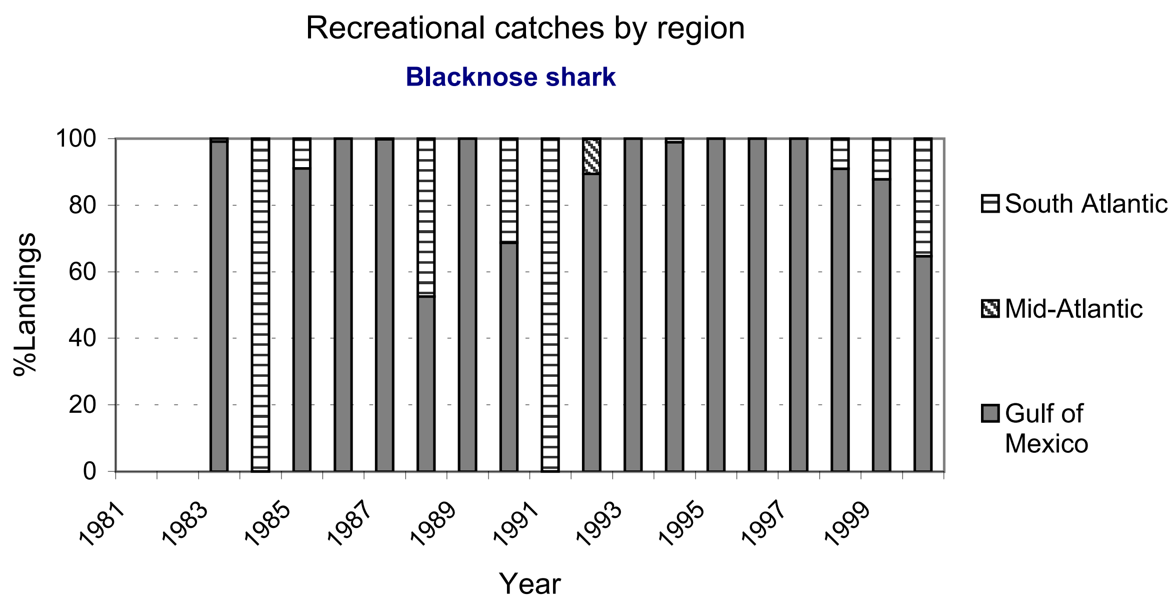



**Figure 9.** Recreational catches of bonnethead by region

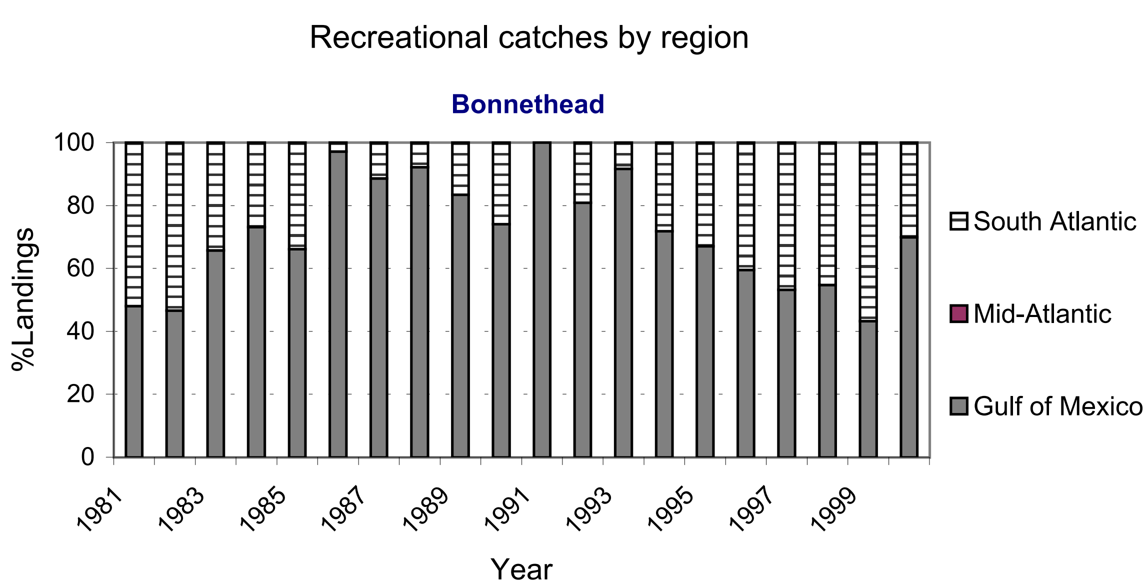


**Figure 10.** Recreational catches of finetooth shark by region

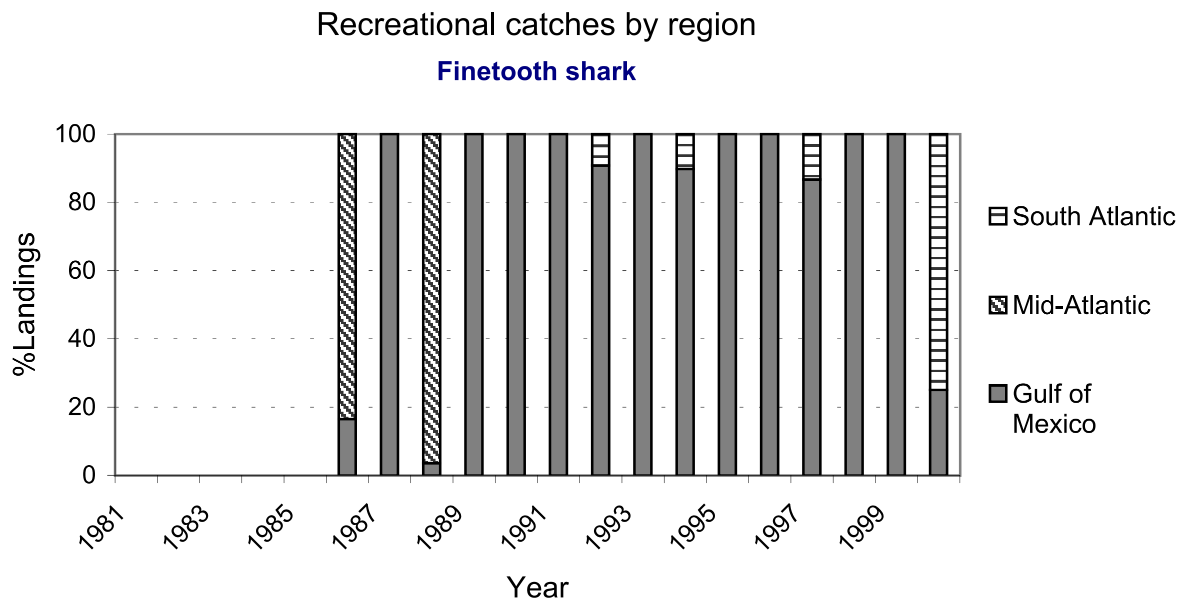
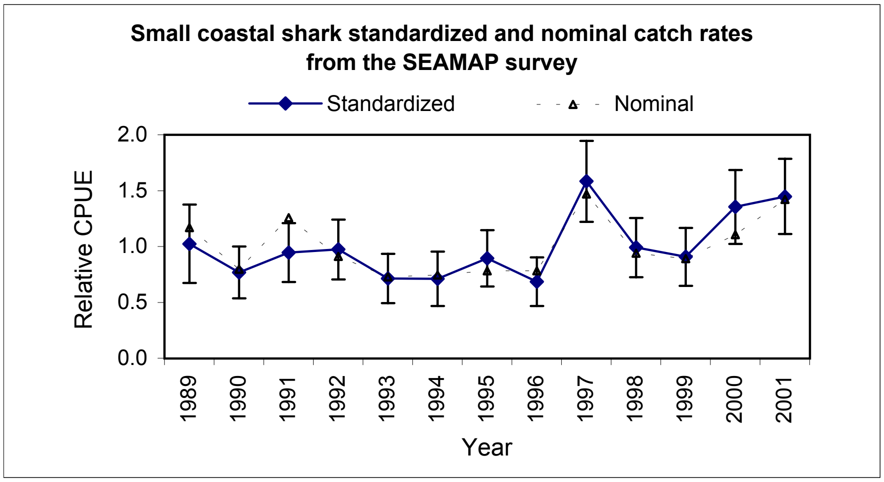
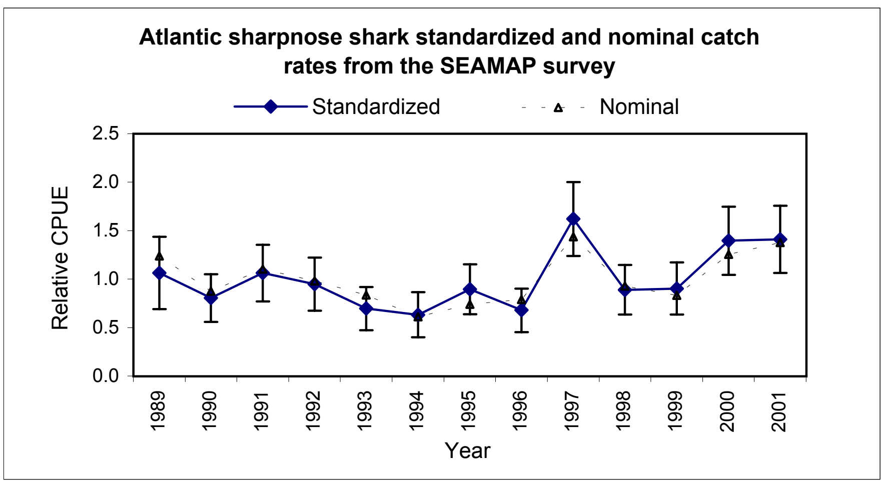


**Figure 11.** Relative nominal and standardized catch rates of small coastal sharks, Atlantic sharpnose shark, and bonnethead from SEAMAP survey data. CPUE is the number of sharks caught per 20-minute tow. The broken line denotes the nominal average CPUE and the solid line represents the standardized CPUE (with lower and upper 95% confidence limits).



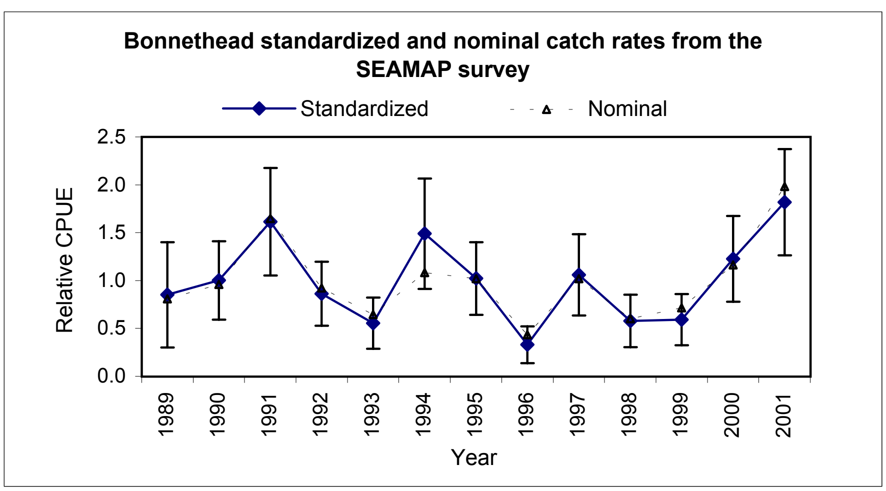
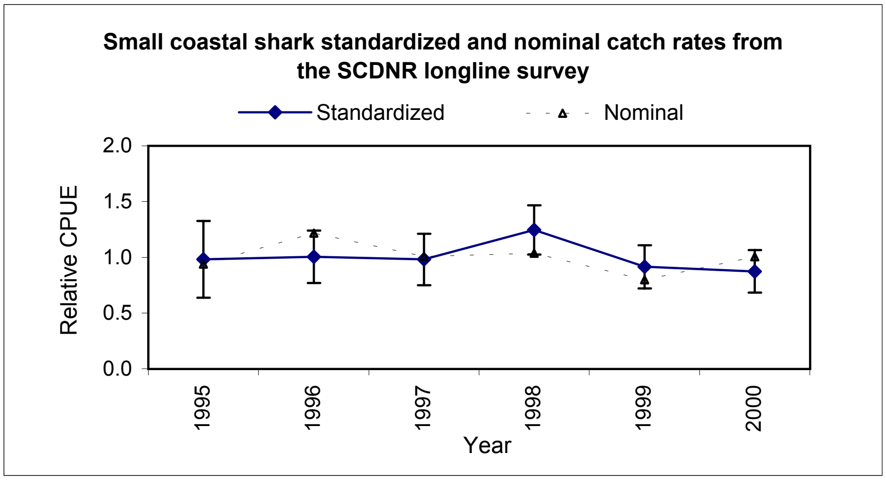
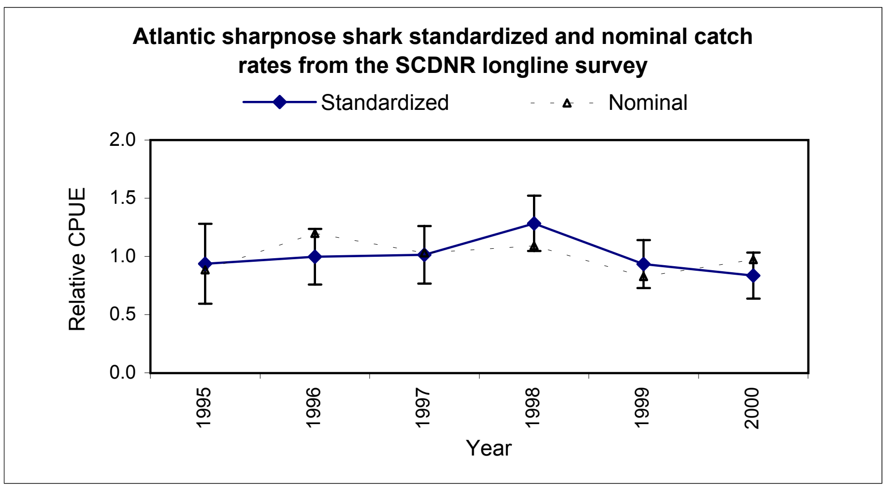



**Figure 12.** Relative nominal and standardized catch rates of small coastal sharks, Atlantic sharpnose shark, and blacknose shark from SCDNR longline survey data. CPUE is the number of sharks caught per 120 hooks per 0.75 hours. The broken line denotes the nominal average CPUE and the solid line represents the standardized CPUE (with lower and upper 95% confidence limits).



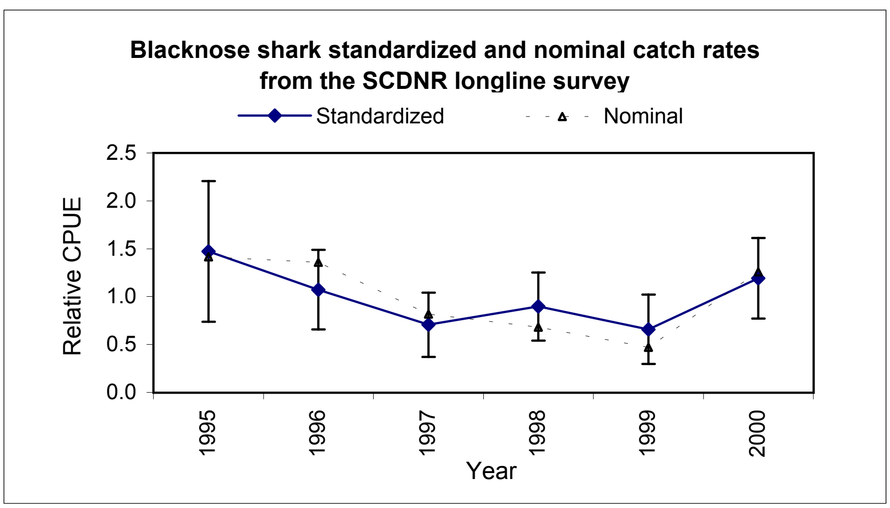
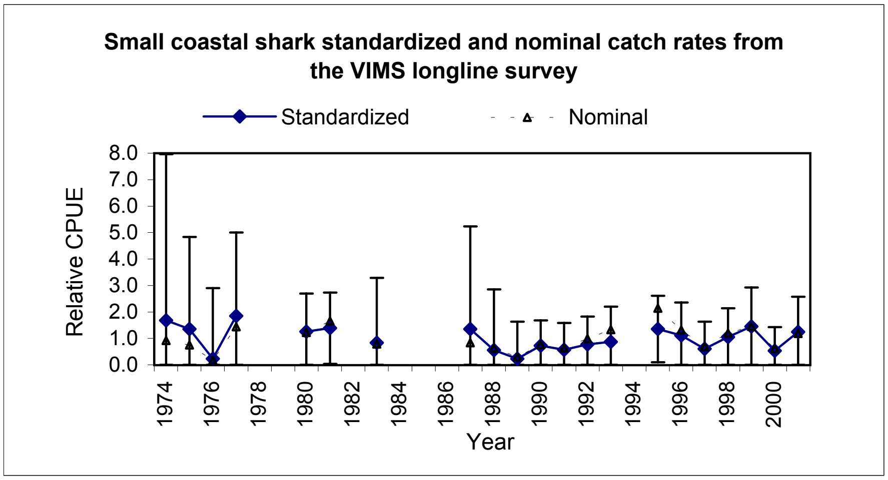



**Figure 13.** Relative nominal and standardized catch rates of small coastal sharks and Atlantic sharpnose shark from VIMS longline survey data. CPUE is the number of sharks caught per 100 hooks per hour. The broken line denotes the nominal average CPUE and the solid line represents the standardized CPUE (with lower and upper 95% confidence limits).



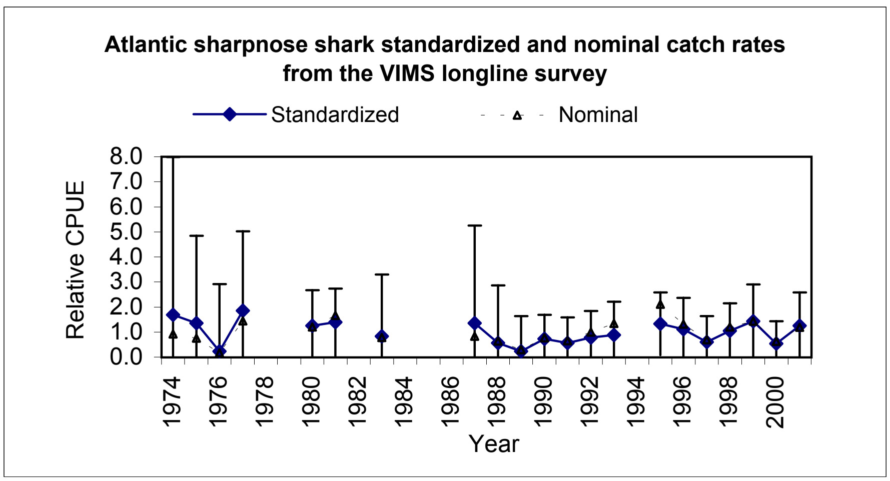
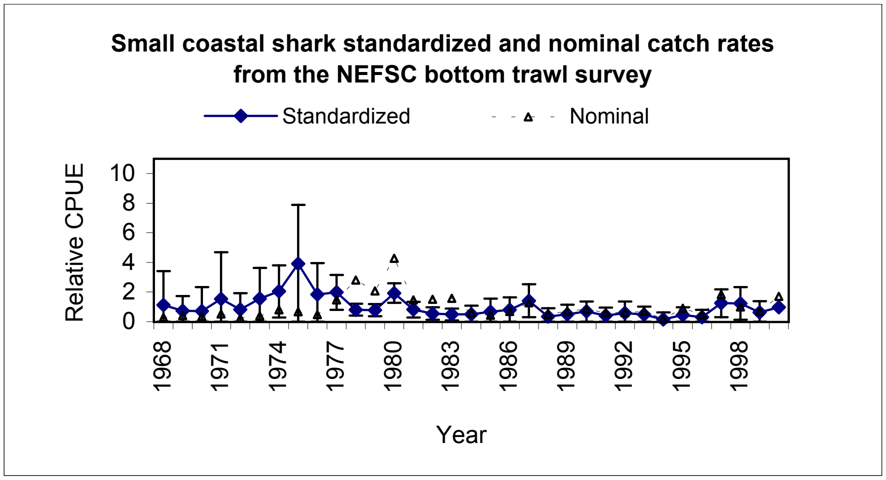
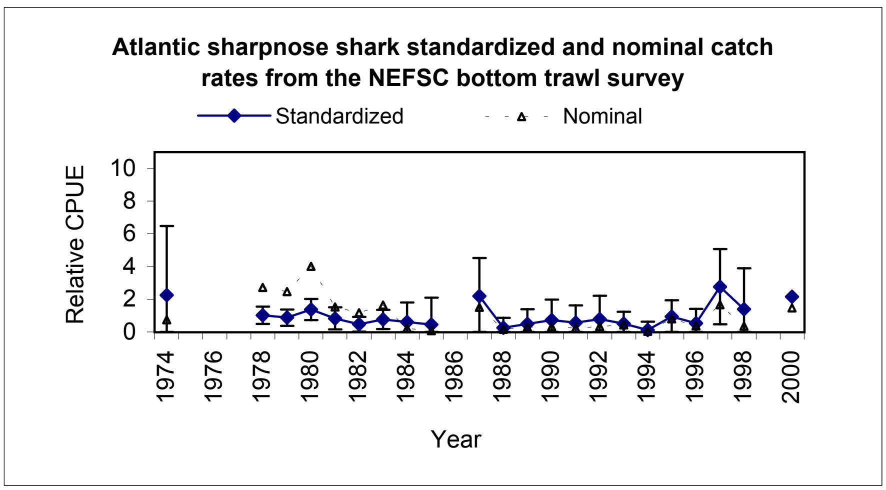



**Figure 14.** Relative nominal and standardized catch rates of small coastal sharks, Atlantic sharpnose shark, and Atlantic angel shark from NEFSC trawl survey data. CPUE is the number of sharks caught per 30-minute tow. The broken line denotes the nominal average CPUE and the solid line represents the standardized CPUE (with lower and upper 95% confidence limits).



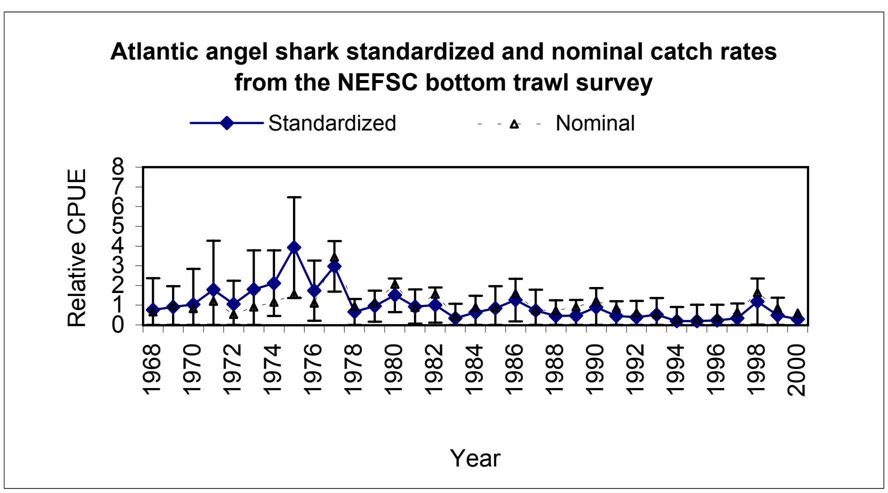



**Figure 15.** Posterior distributions for population parameters and management quantities for the **small coastal shark aggregate** obtained with the Bayesian SPM using the Gibbs sampler.

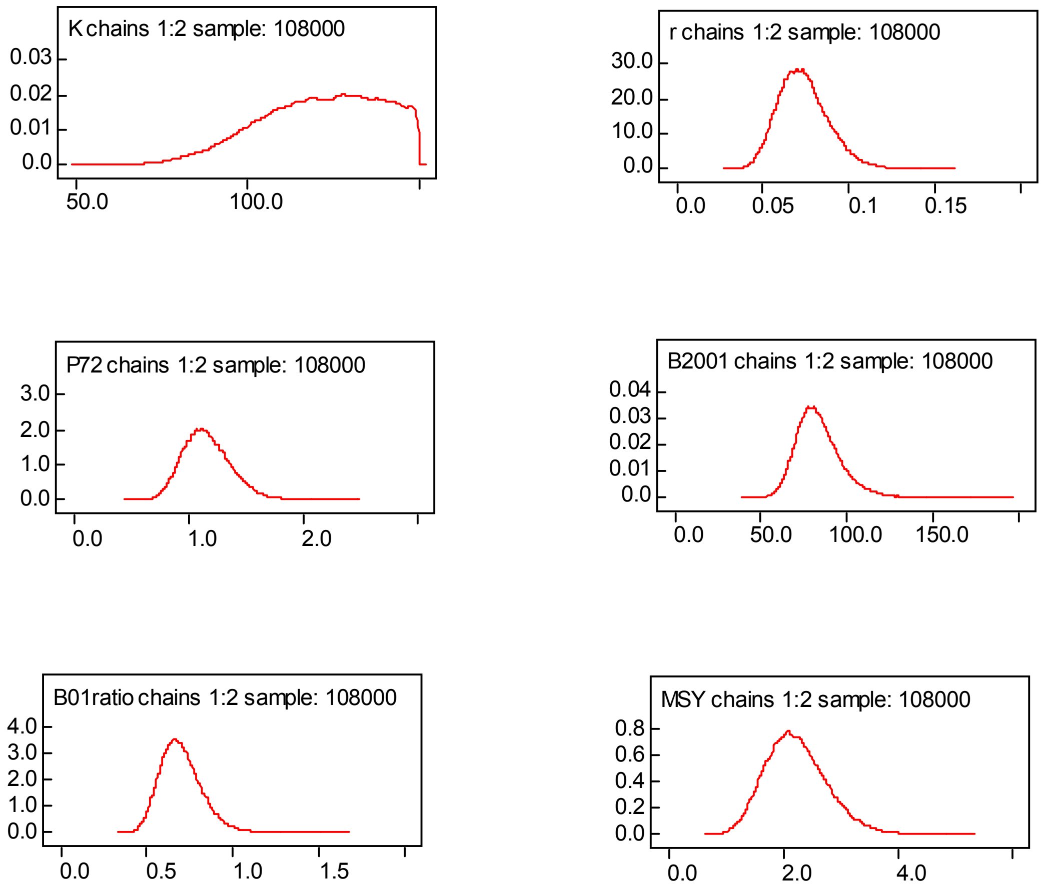
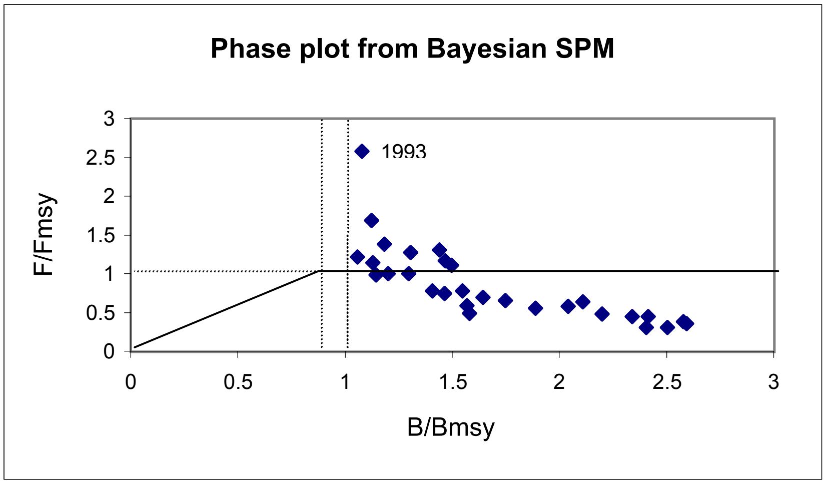
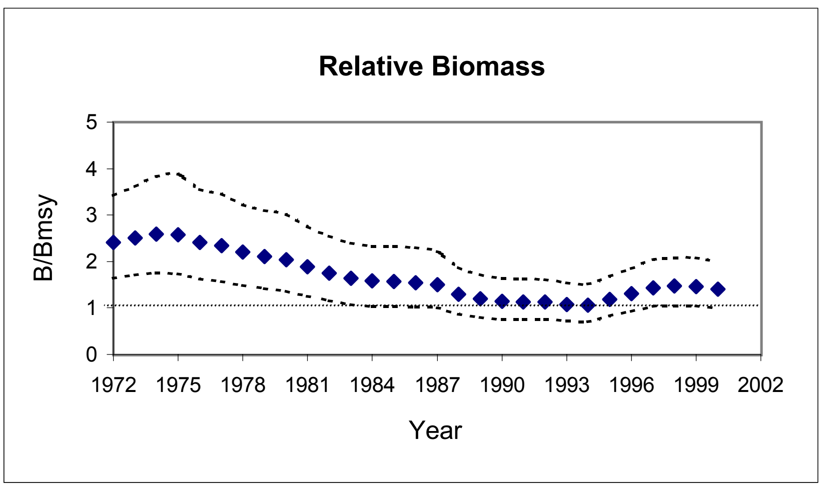


**Figure 16.** Phase plot and estimated trajectories of relative biomass and relative fishing mortality for the **small coastal shark aggregate** obtained with the Bayesian SPM using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



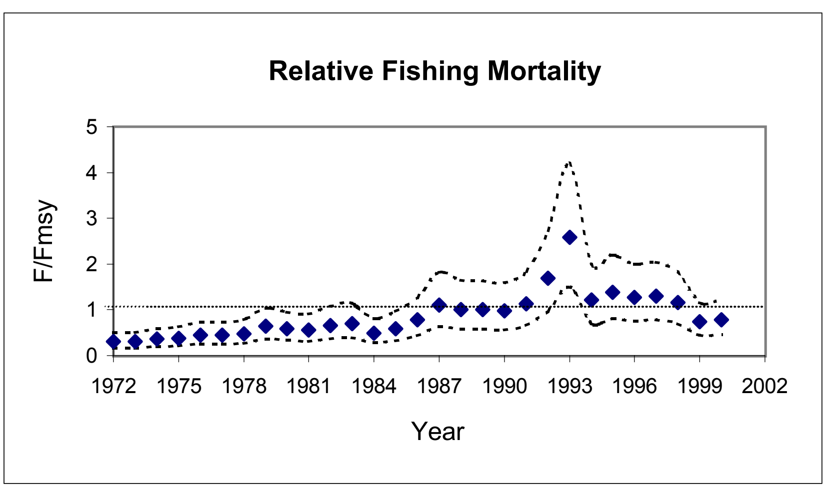



**Figure 17.** Posterior distributions for population parameters and management quantities for **Atlantic sharpnose shark** obtained with the Bayesian SPM using the Gibbs sampler.

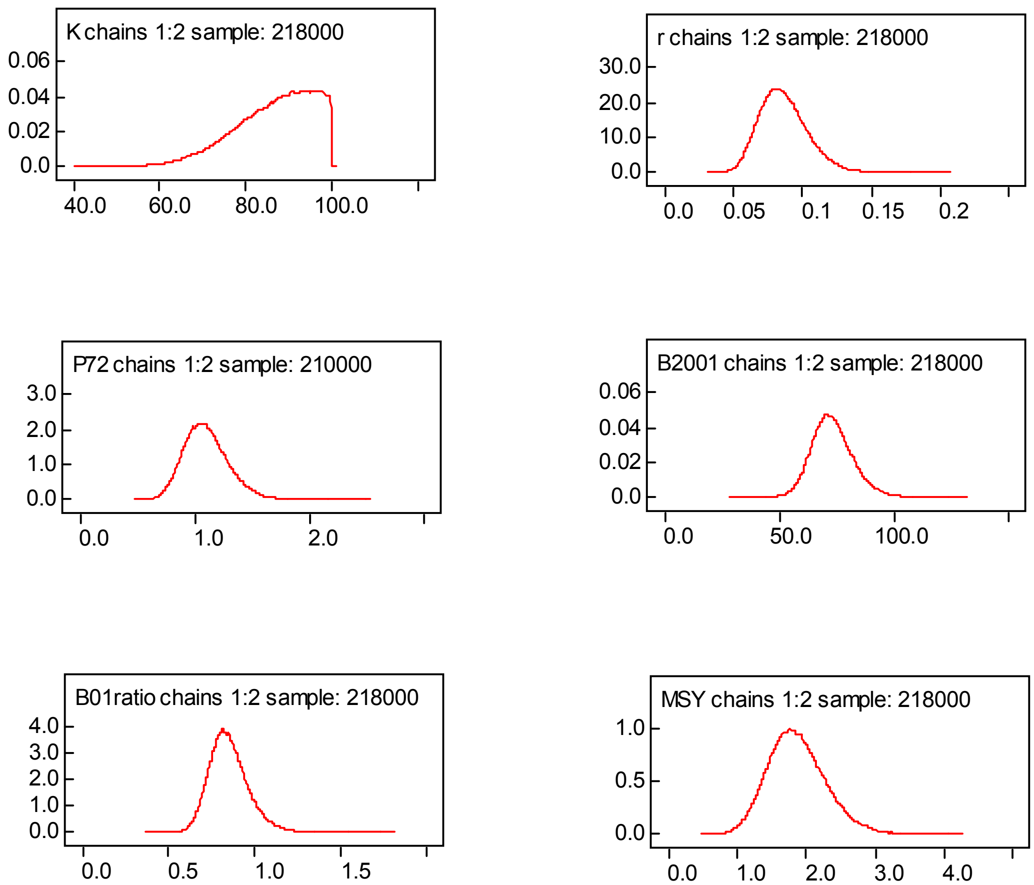
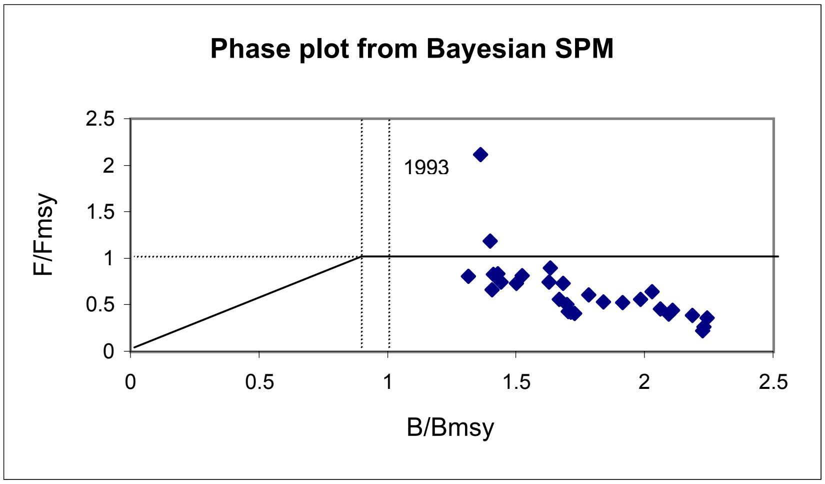
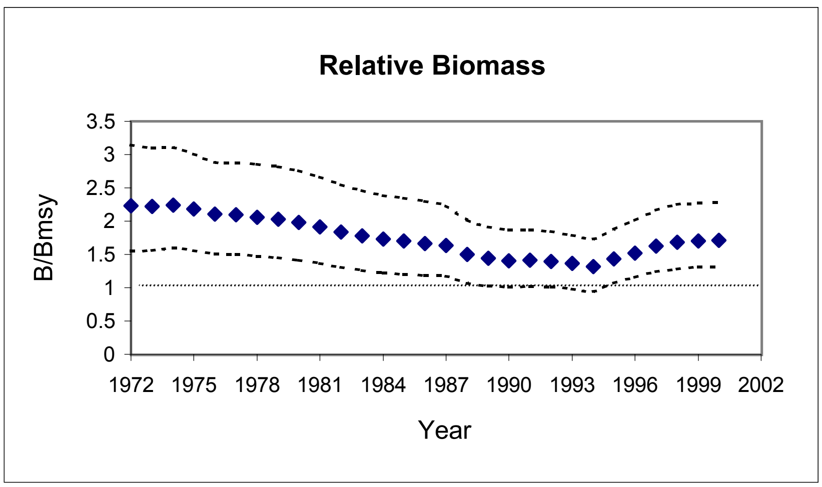


**Figure 18.** Phase plot and estimated trajectories of relative biomass and relative fishing mortality for **Atlantic sharpnose shark** obtained with the Bayesian SPM using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



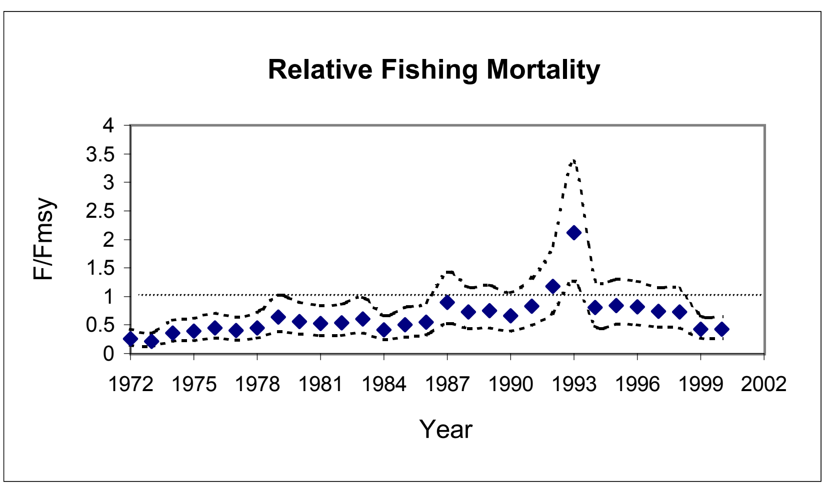



**Figure 19.** Posterior distributions for population parameters and management quantities for **bonnethead** obtained with the Bayesian SPM using the Gibbs sampler.

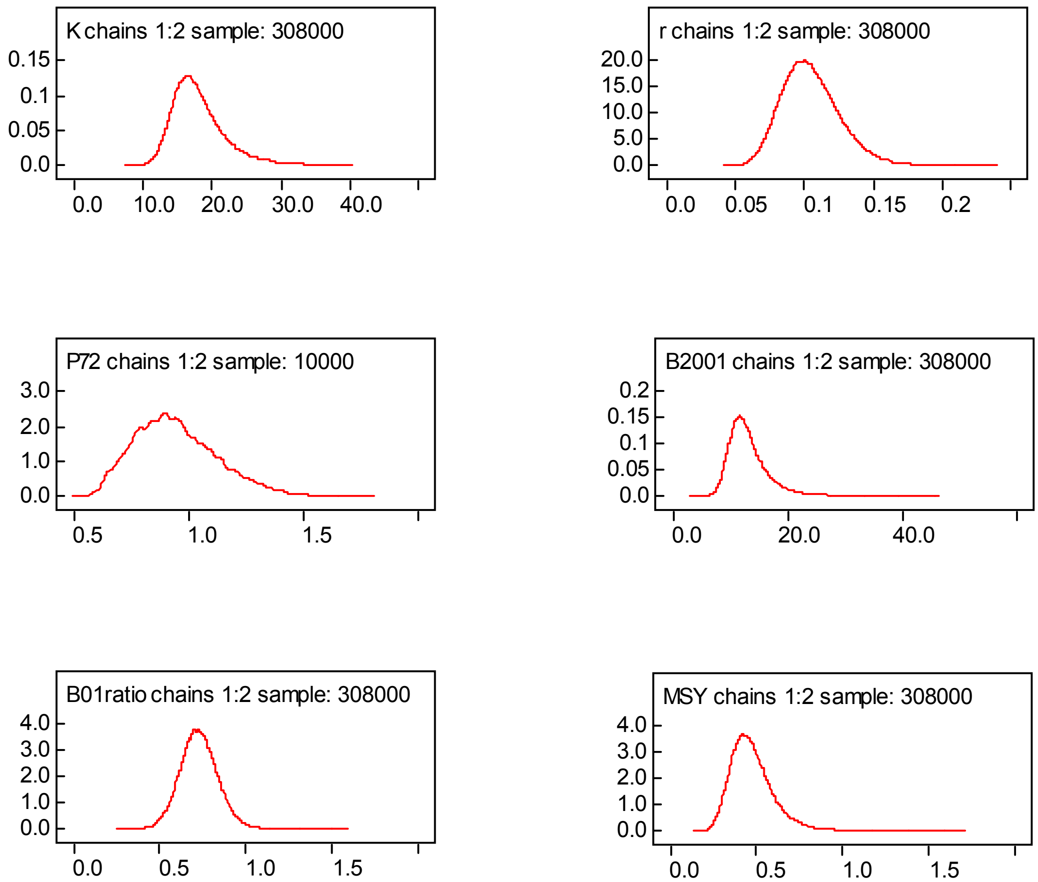


**Figure 20.** Phase plot and estimated trajectories of relative biomass and relative fishing mortality for **bonnethead** obtained with the Bayesian SPM using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.

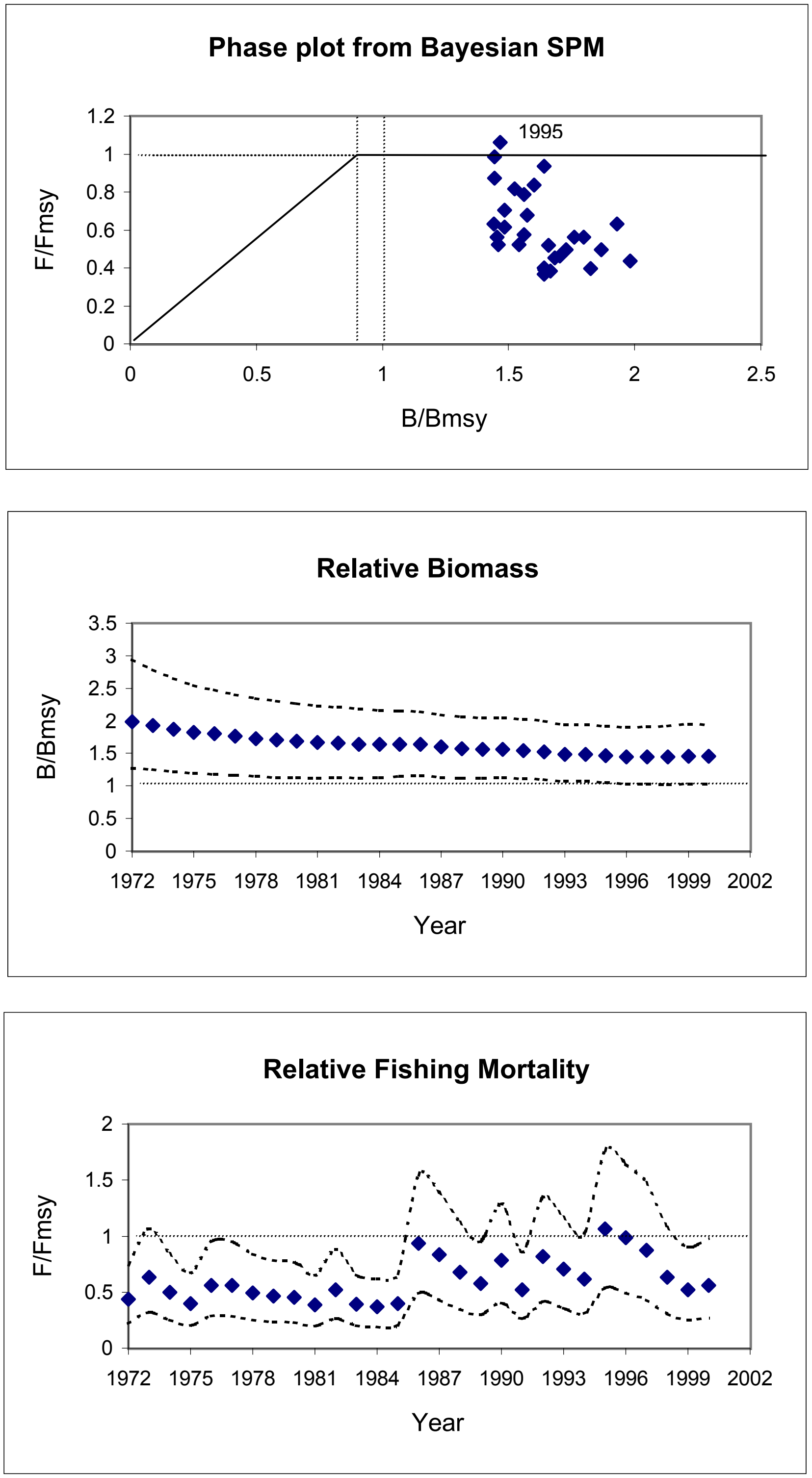


**Figure 21.** Posterior distributions for population parameters and management quantities for the **blacknose shark** obtained with the Bayesian SPM using the Gibbs sampler.

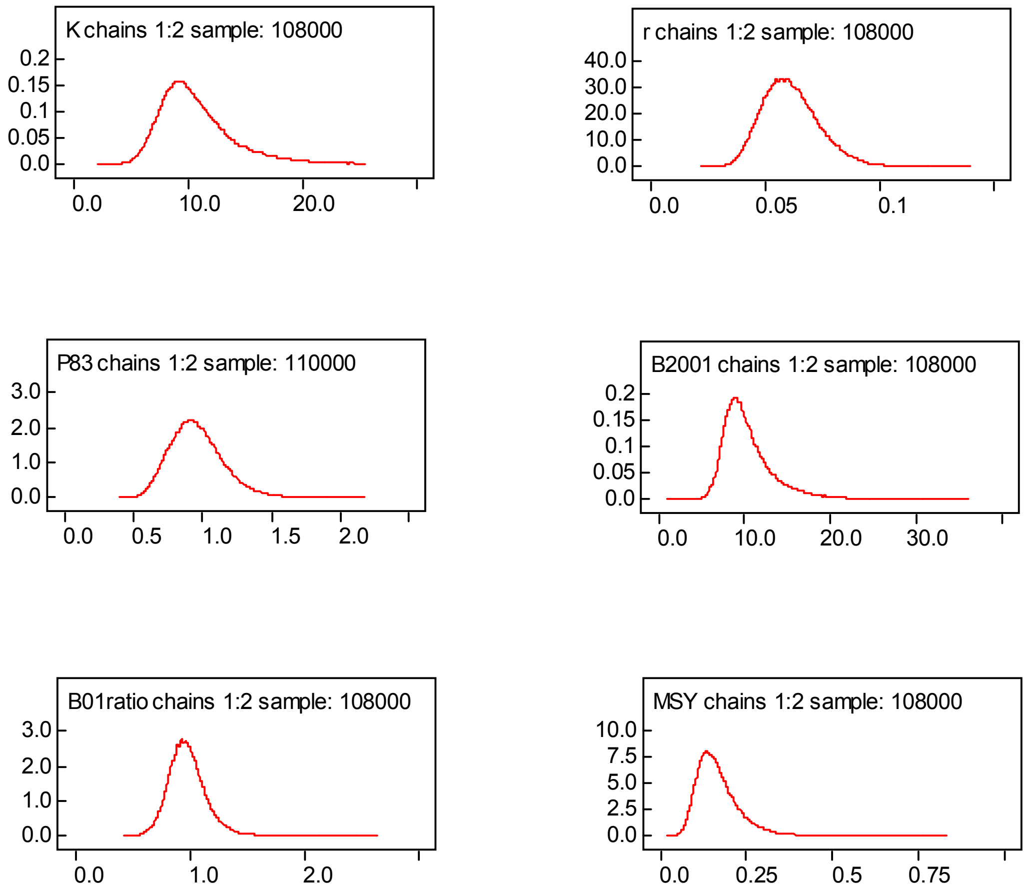


**Figure 22.** Phase plot and estimated trajectories of relative biomass and relative fishing mortality for **blacknose shark** obtained with the Bayesian SPM using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.

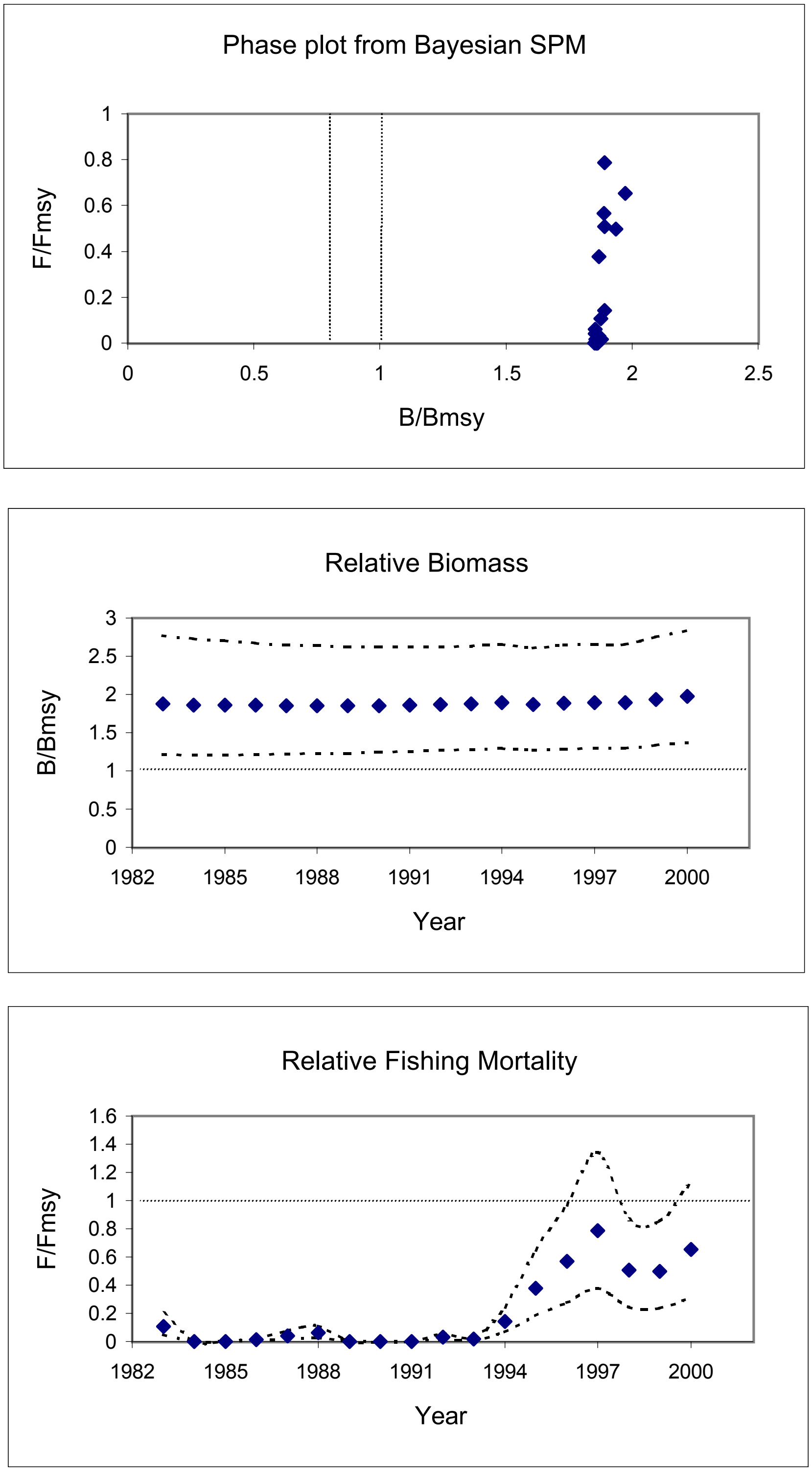


**Figure 23.** Posterior distributions for population parameters and management quantities for the **finetooth shark** obtained with the Bayesian SPM using the Gibbs sampler.

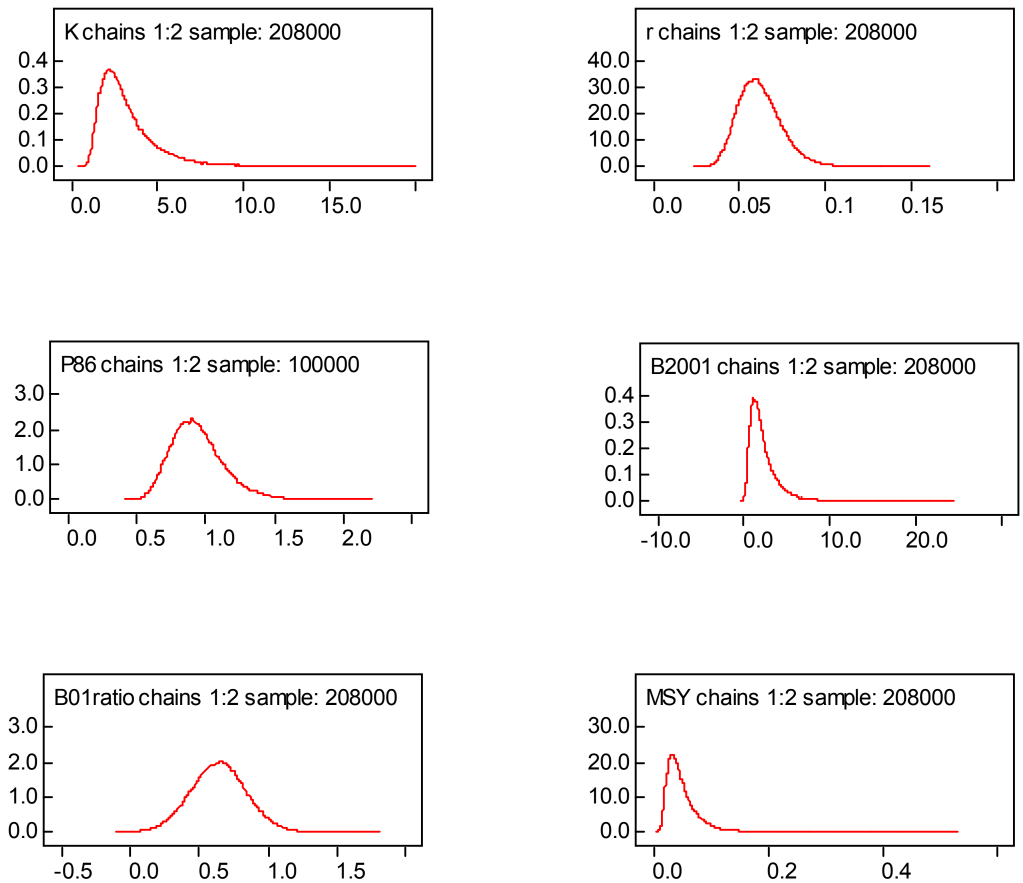
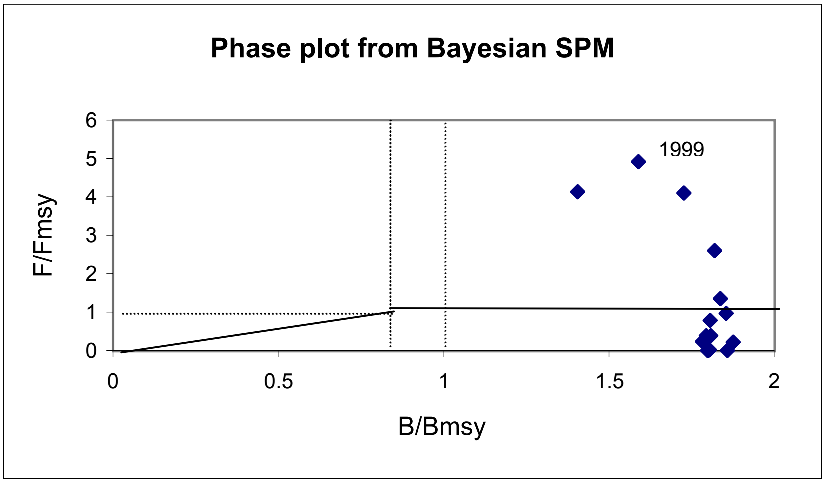
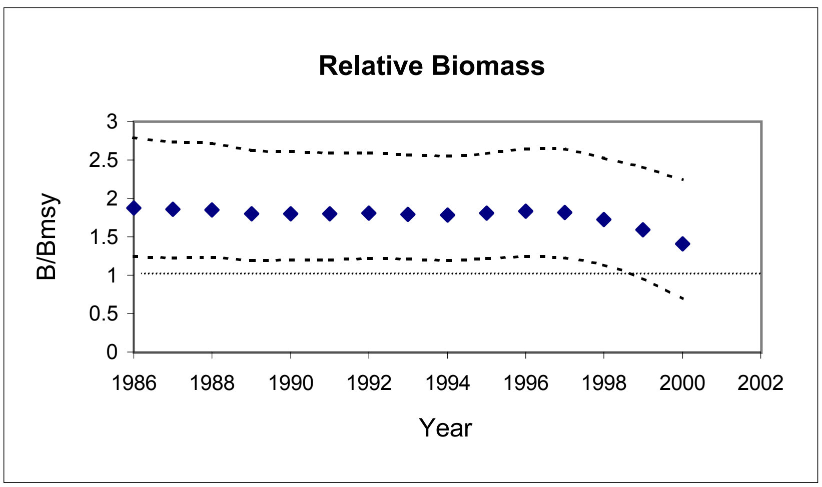


**Figure 24.** Phase plot and estimated trajectories of relative biomass and relative fishing mortality for the **finetooth shark** obtained with the Bayesian SPM using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



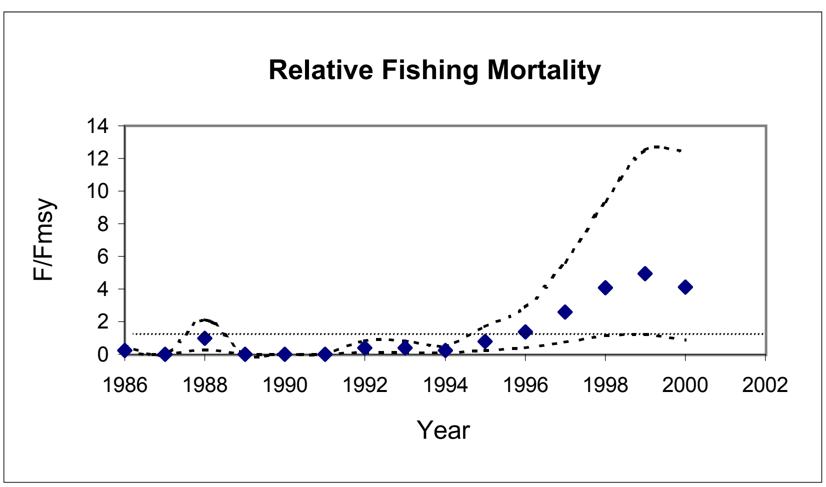



**Figure 25.** Posterior distributions for population parameters and management quantities for the **small coastal shark aggregate** obtained with the Bayesian LRSG model using the Gibbs sampler.

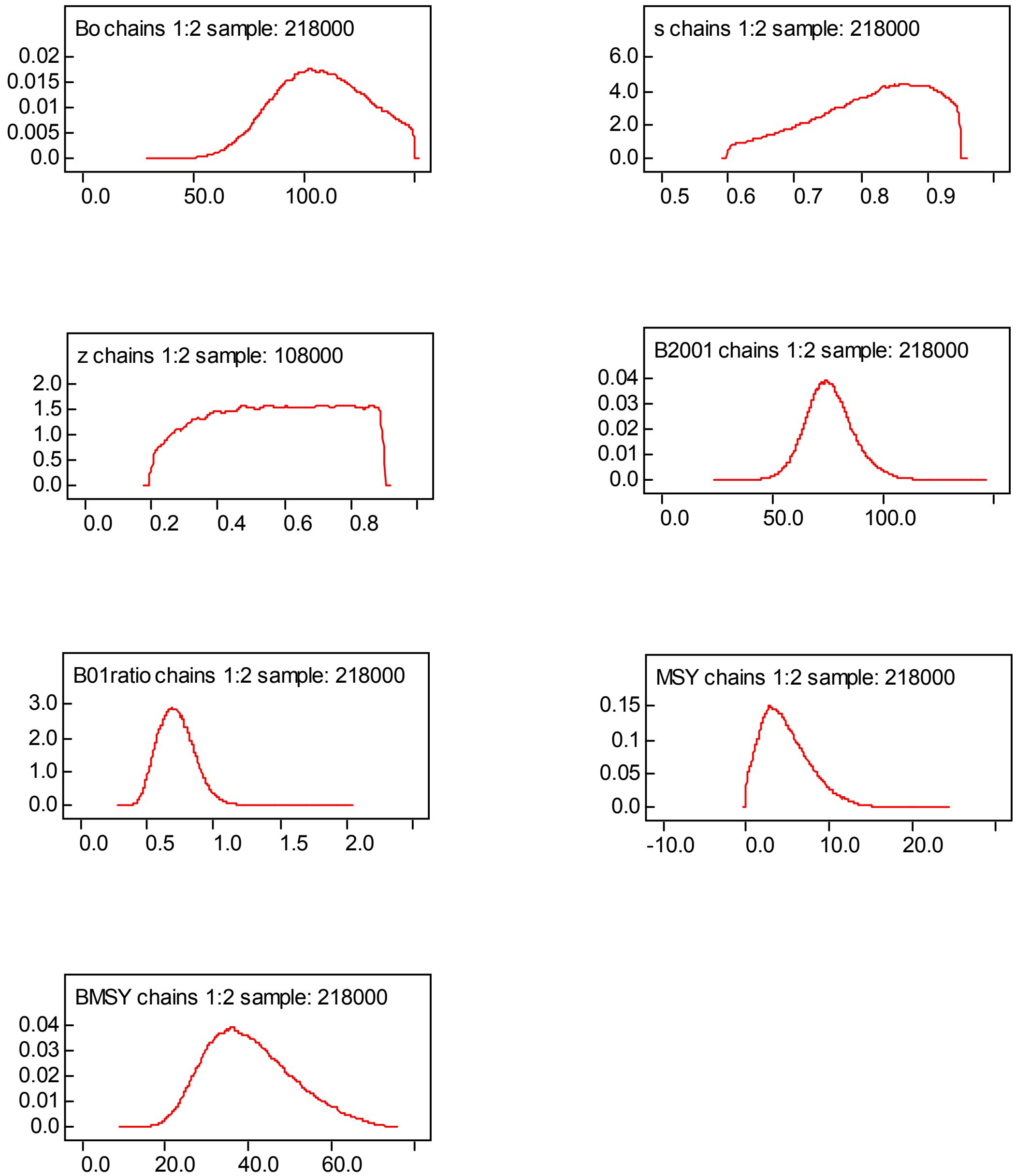
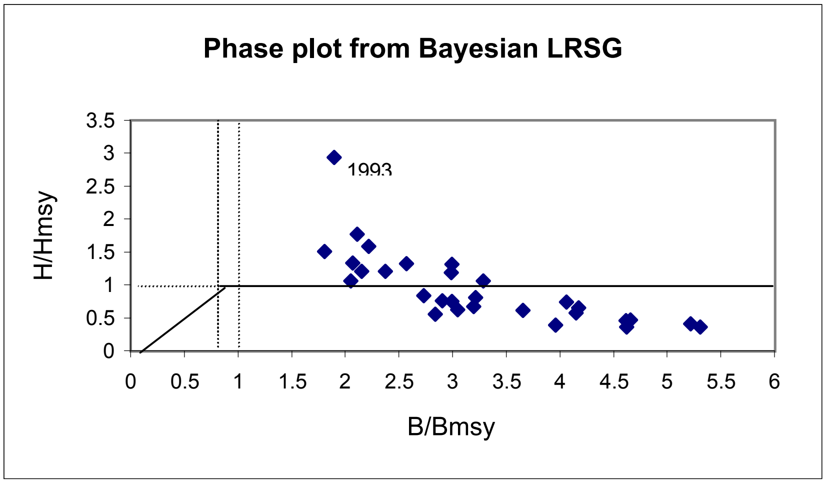
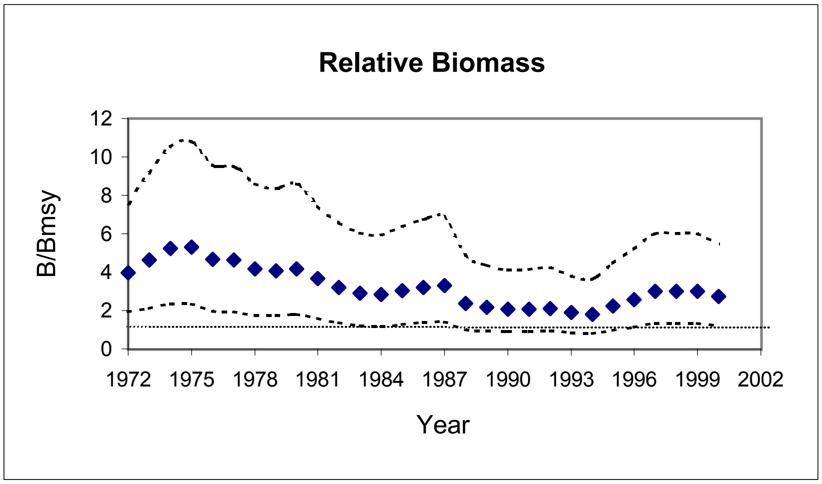


**Figure 26.** Phase plot and estimated trajectories of relative biomass and relative harvest rate for the **small coastal shark aggregate** obtained with the Bayesian LRSG using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



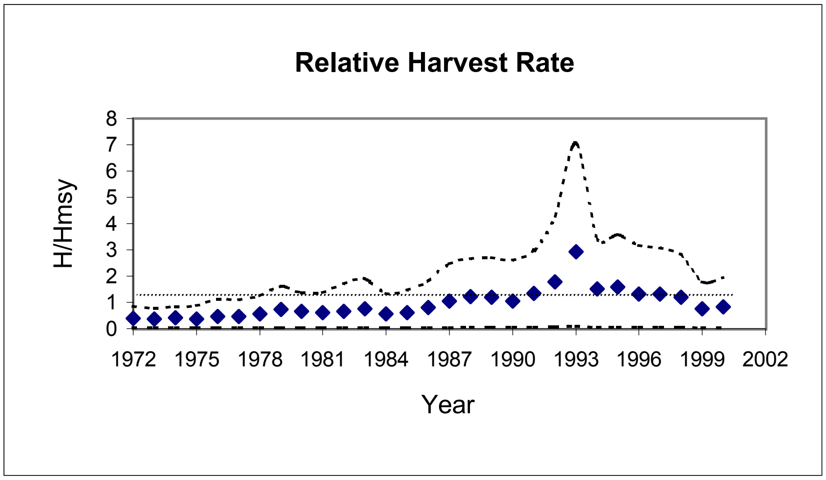



**Figure 27.** Posterior distributions for population parameters and management quantities for the **Atlantic sharpnose shark** obtained with the Bayesian LRSG model using the Gibbs sampler.

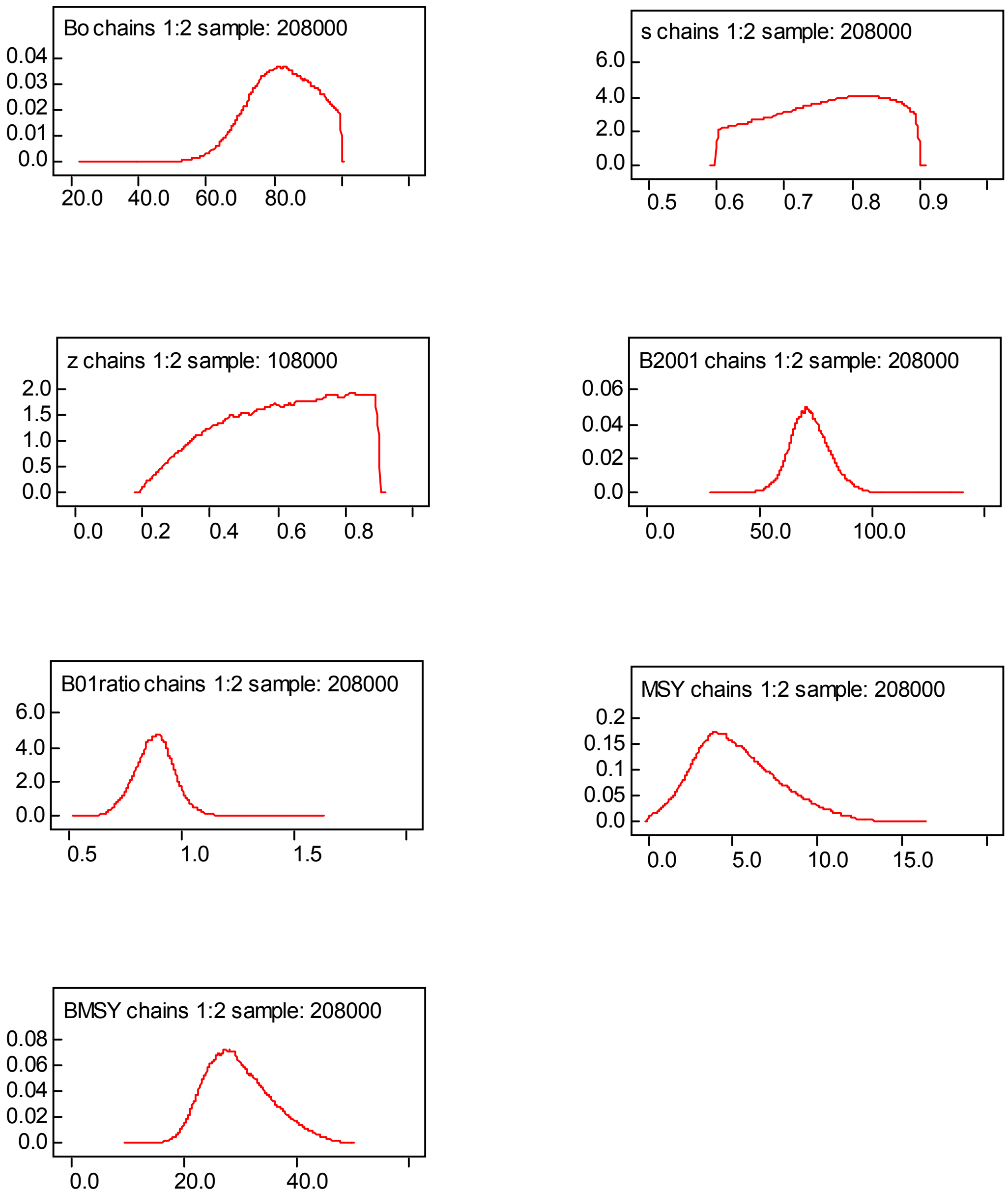
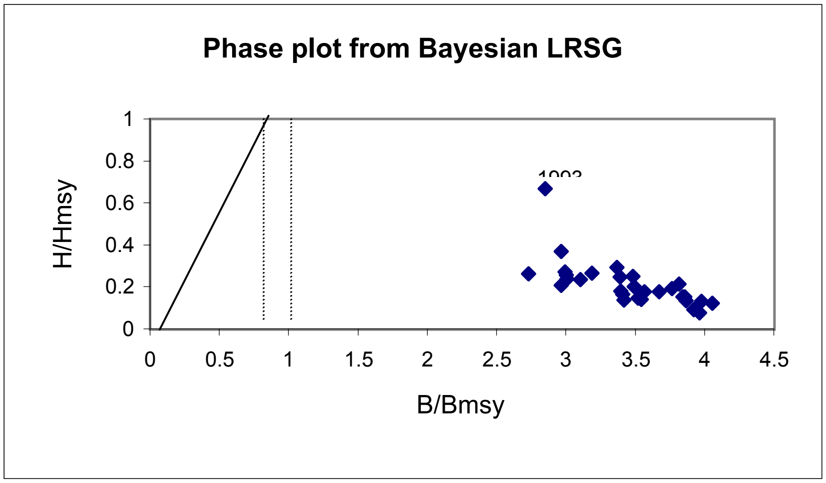
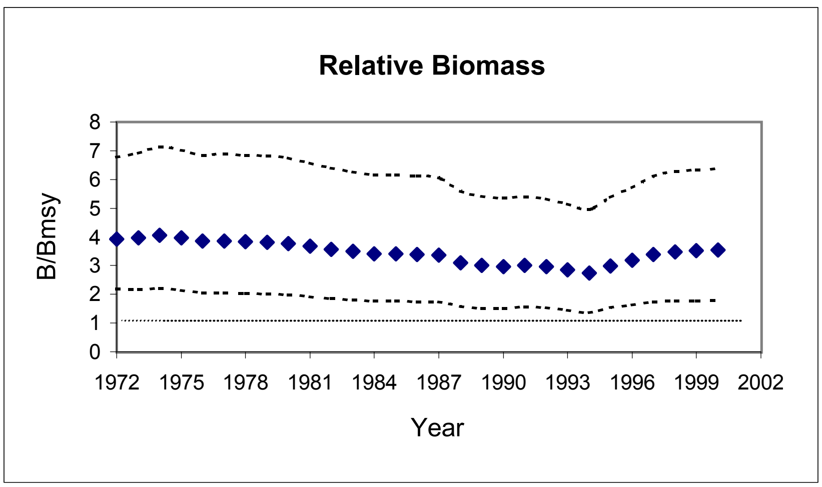


**Figure 28.** Phase plot and estimated trajectories of relative biomass and relative harvest rate for **Atlantic sharpnose shark** obtained with the Bayesian LRSG using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



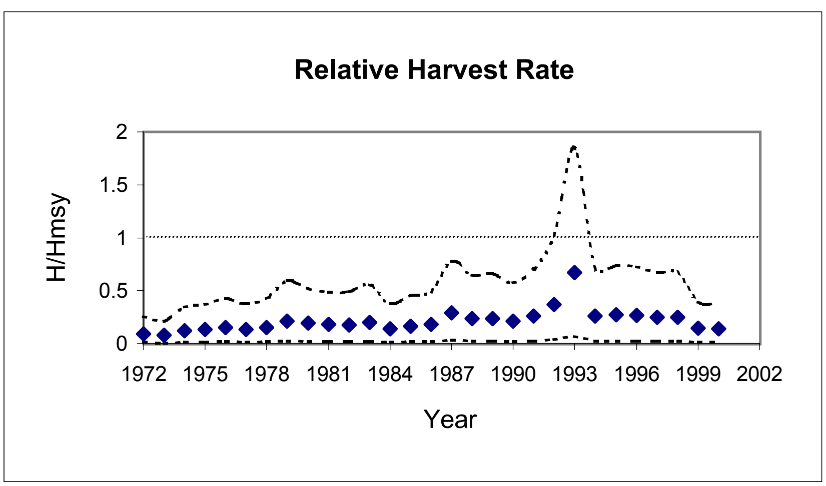



**Figure 29.** Posterior distributions for population parameters and management quantities for the **bonnethead** obtained with the Bayesian LRSG model using the Gibbs sampler.

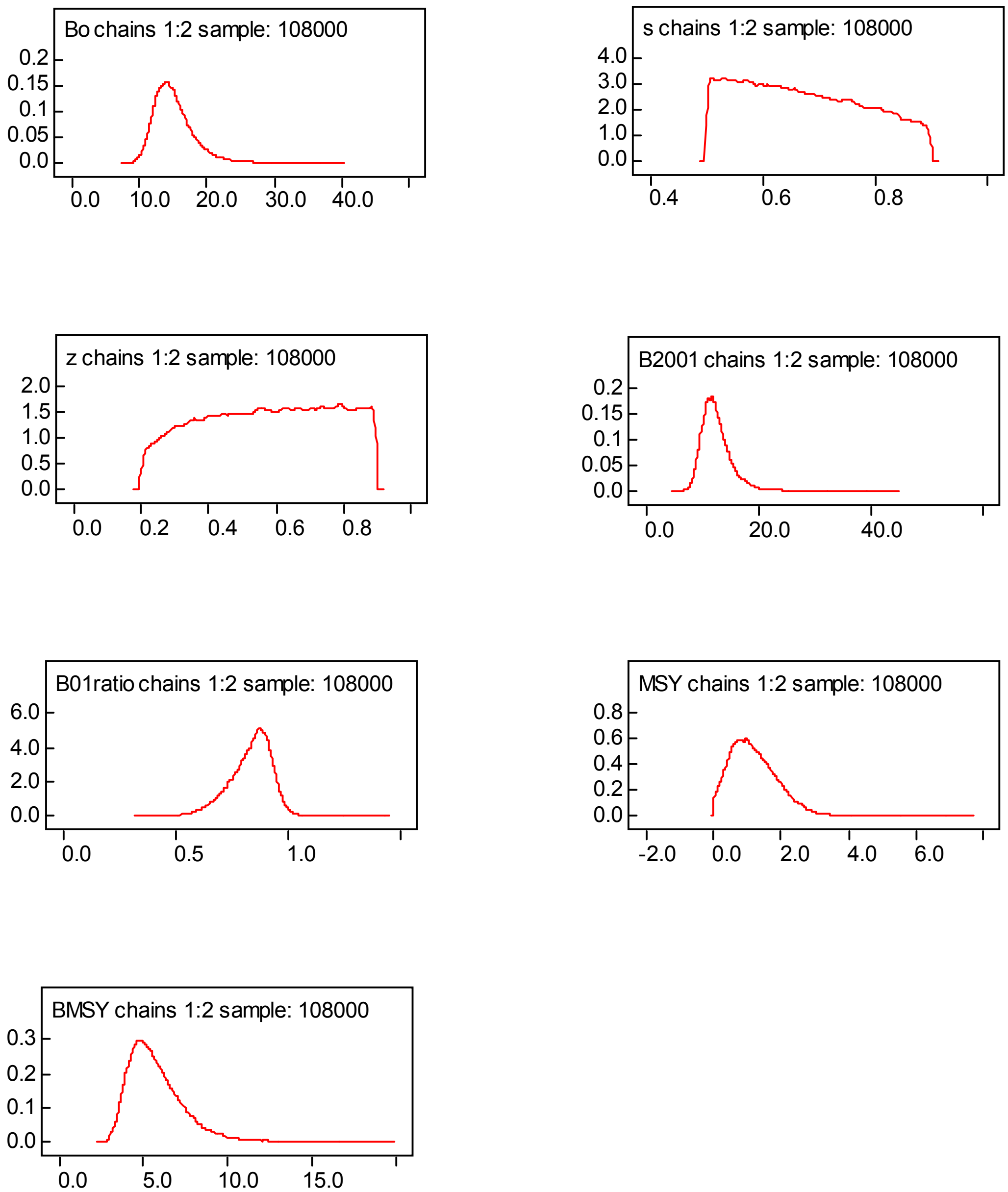
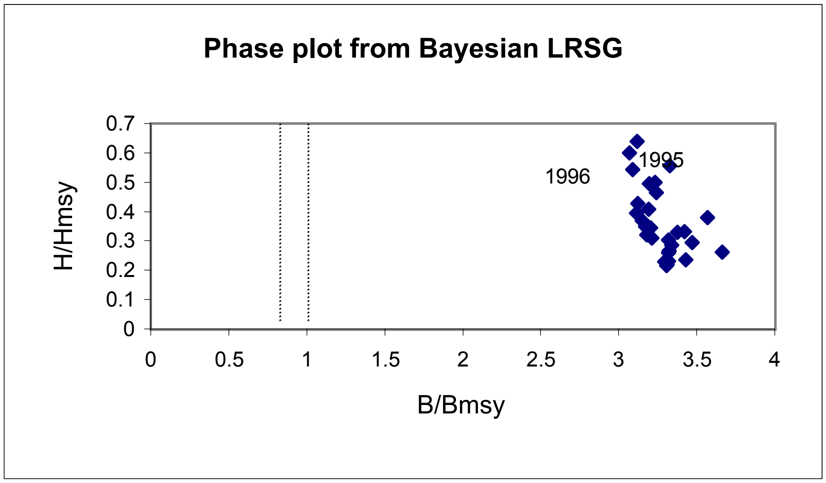
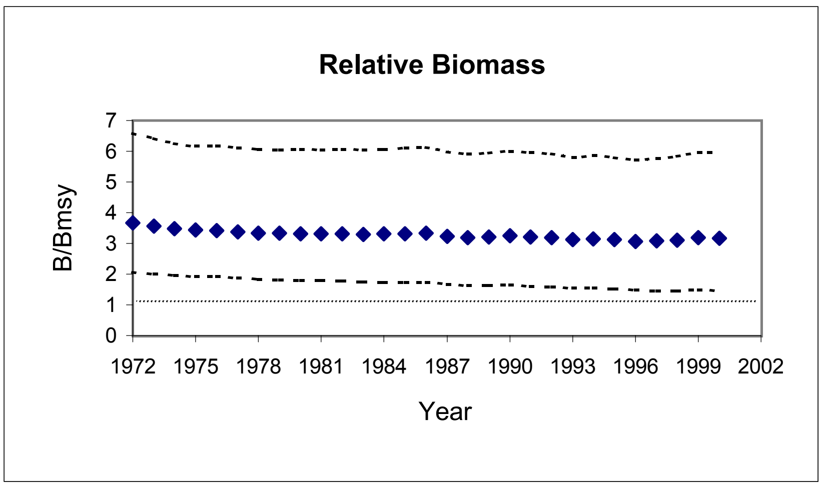


**Figure 30.** Phase plot and estimated trajectories of relative biomass and relative harvest rate for **bonnethead** obtained with the Bayesian LRSG using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



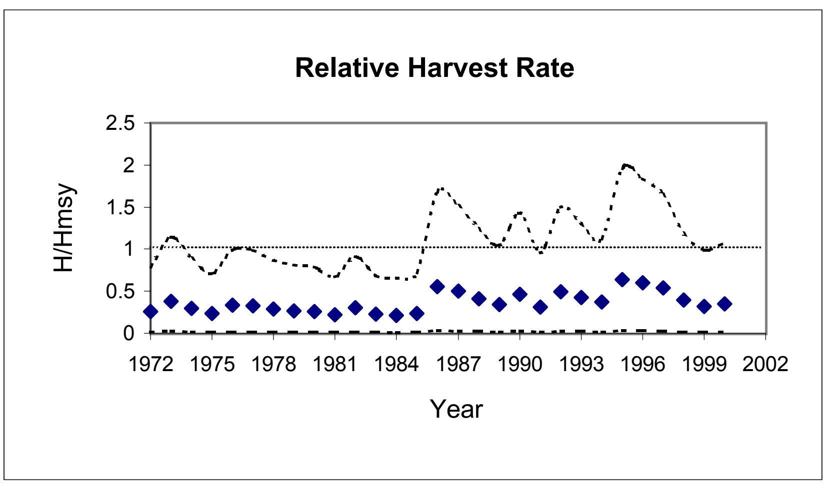



**Figure 31.** Posterior distributions for population parameters and management quantities for the **blacknose shark** obtained with the Bayesian LRSG model using the Gibbs sampler.

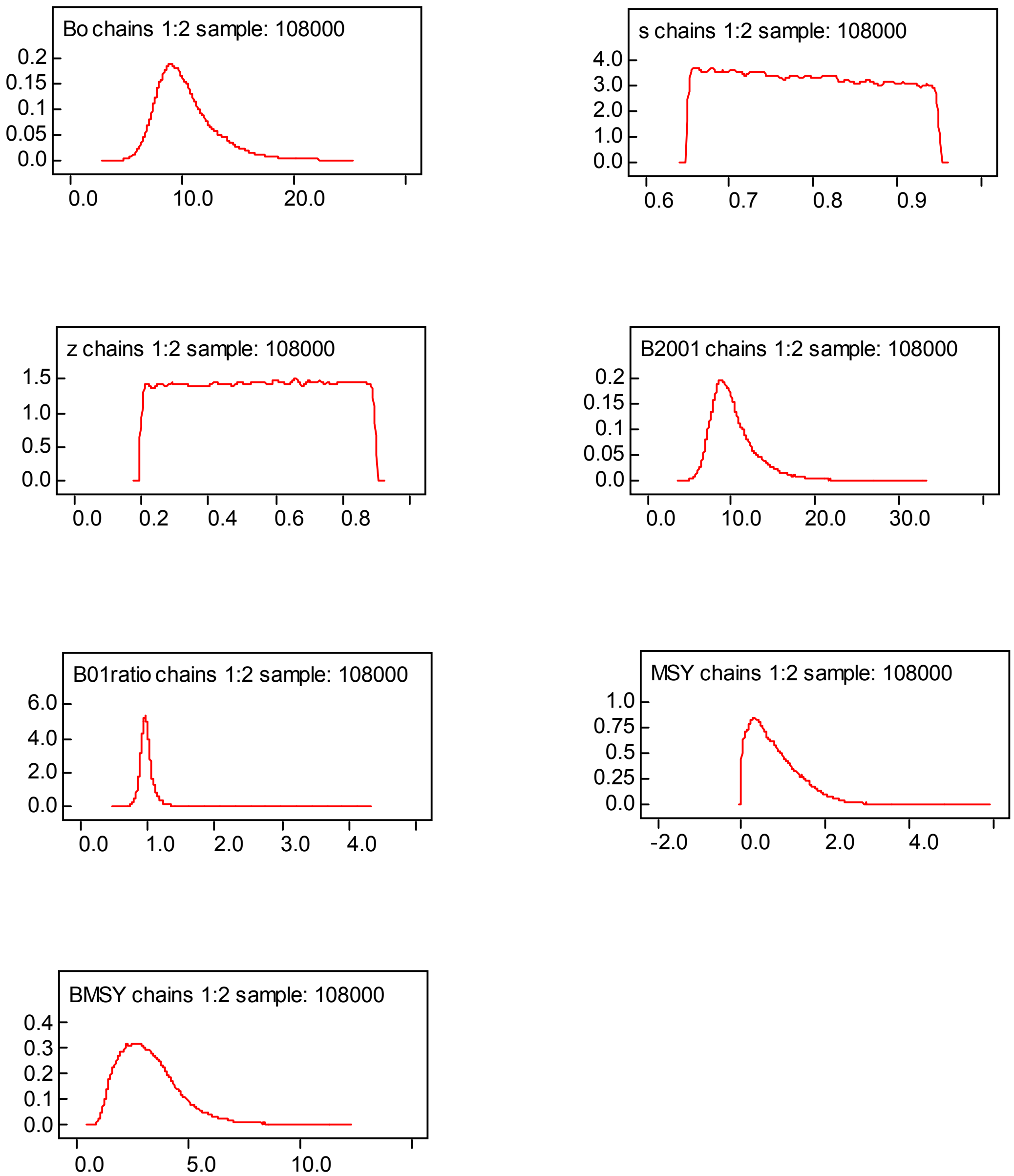
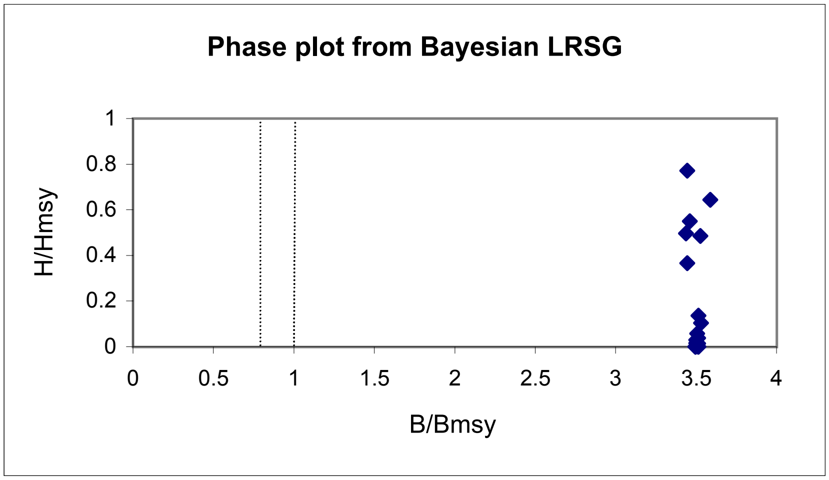
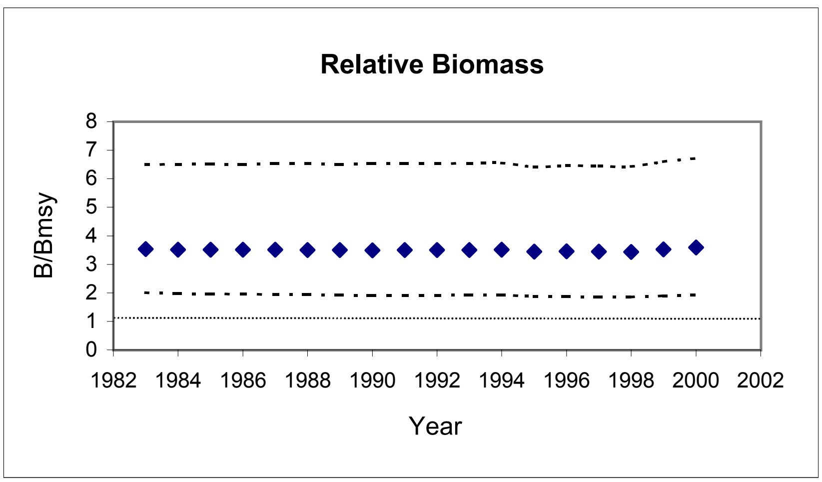


**Figure 32.** Phase plot and estimated trajectories of relative biomass and relative harvest rate for **blacknose shark** obtained with the Bayesian LRSG using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



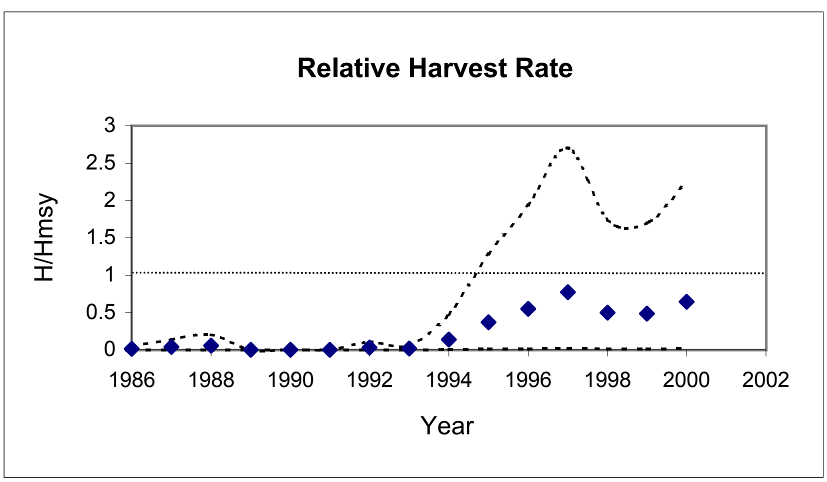



**Figure 33.** Posterior distributions for population parameters and management quantities for the **finetooth shark** obtained with the Bayesian LRSG model using the Gibbs sampler.

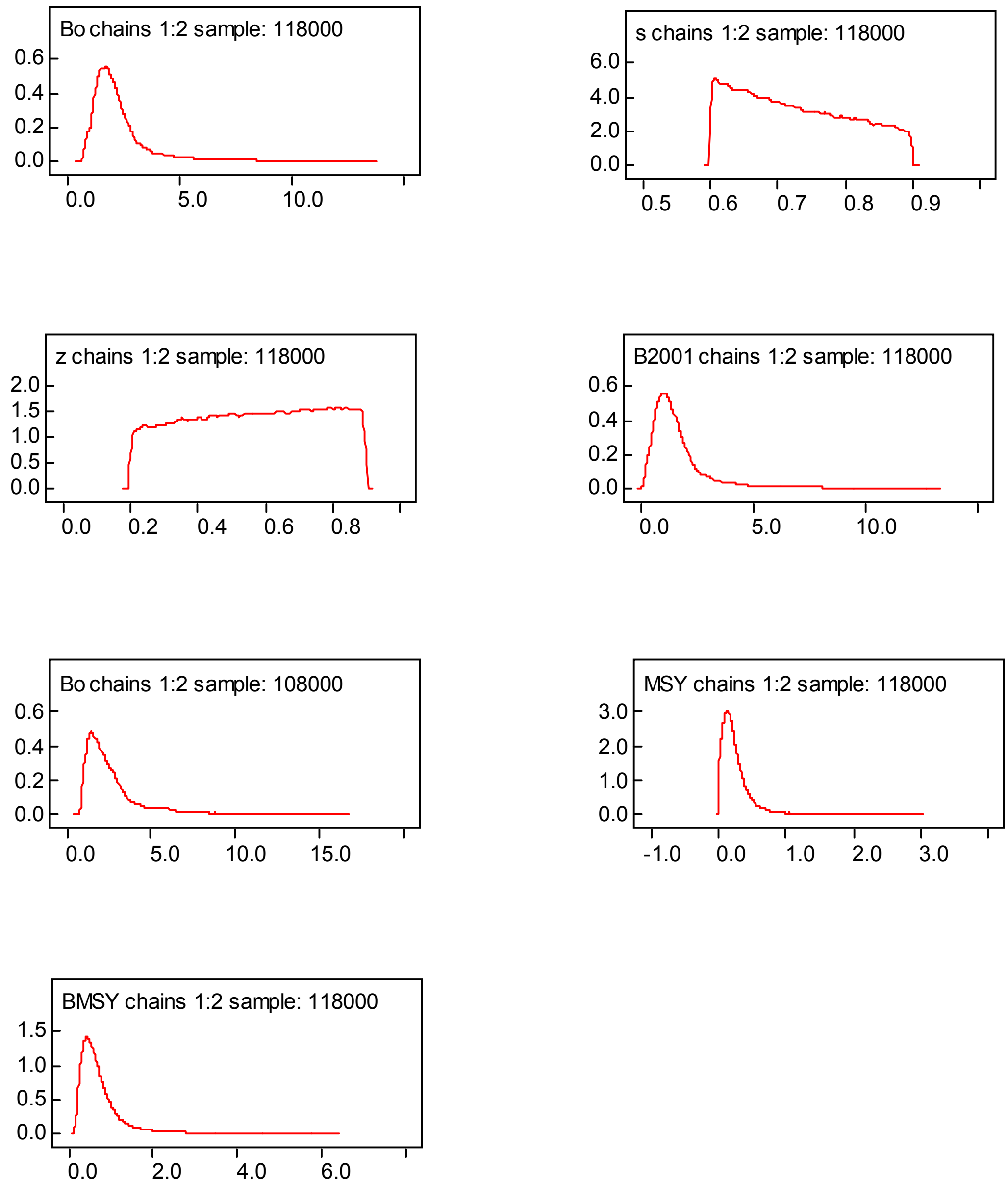
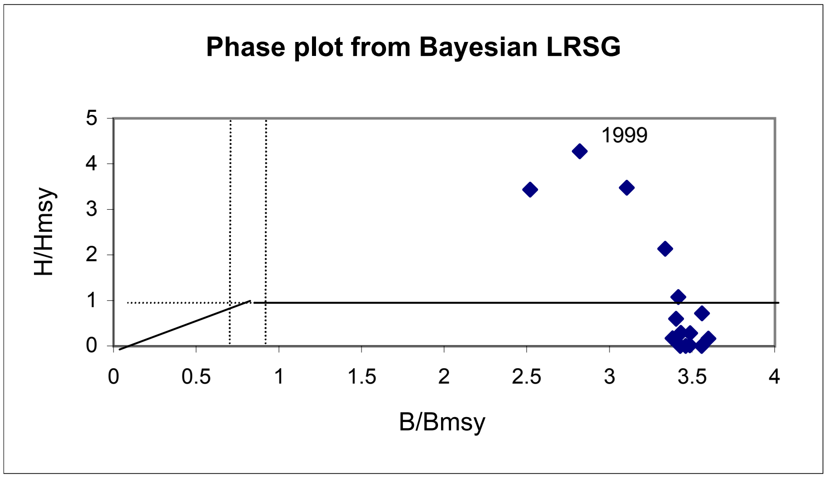
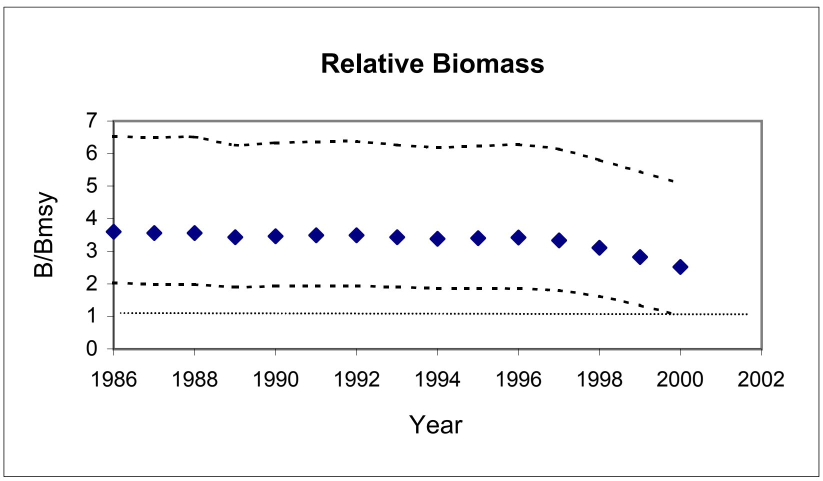
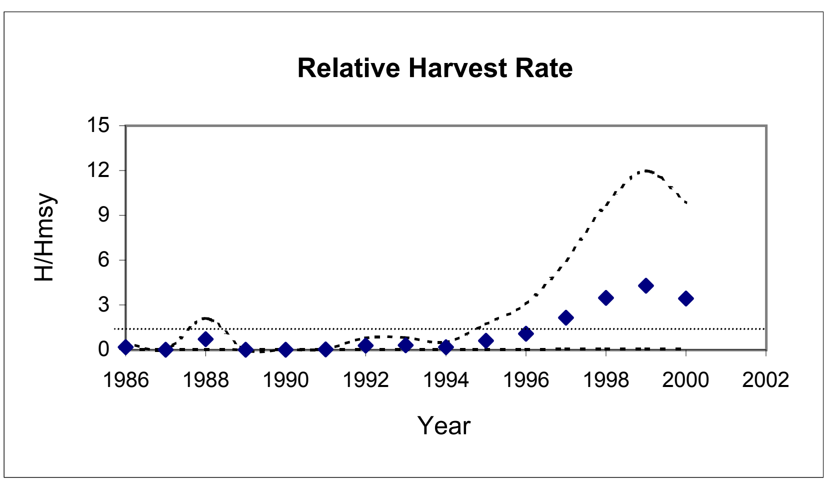


**Figure 34.** Phase plot and estimated trajectories of relative biomass and relative harvest rate for **finetooth shark** obtained with the Bayesian LRSG using the Gibbs sampler. Values are means with 2.5th and 97.5th percentiles.



**Appendix 1.** CPUE Series for Small Coastal Sharks

Available CPUE series for small coastal sharks. Series are listed by species or species group, with source of information indicated. The index is the estimated mean CPUE and the CV is the estimated precision of the mean value. Type refers to whether the index is fishery-independent or fishery-dependent. Observations with a CV of 1.0 are either nominal data for which no measure of the precision of the estimate was available (whole series) or estimates with very small sample sizes for which an estimate of CV could not be computed (individual years within series). The column 'Standardized?" refers to whether the series was standardized through GLM procedures.

| Series name | Type | Year | Index | CV | Standardized? |
|---|---|---|---|---|---|
| | | | | | |
| **Small coastal sharks** | | | | | |
| Oregon II | F-I | 1972 | 0.565 | 0.260 | Yes |
| | | 1973 | 1.009 | 0.182 | |
| | | 1974 | 1.991 | 0.175 | |
| | | 1975 | 1.544 | 0.161 | |
| | | 1976 | 1.612 | 0.143 | |
| | | 1977 | 0.909 | 0.206 | |
| | | 1978 | 0.796 | 0.193 | |
| | | 1979 | 0.987 | 0.211 | |
| | | 1980 | 1.449 | 0.202 | |
| | | 1981 | 0.882 | 0.228 | |
| | | 1982 | 0.952 | 0.199 | |
| | | 1983 | 0.790 | 0.234 | |
| | | 1984 | 0.664 | 0.365 | |
| | | 1985 | 1.069 | 0.344 | |
| | | 1986 | 1.067 | 0.562 | |
| | | 1987 | 4.655 | 0.911 | |
| | | 1988 | 0.269 | 0.456 | |
| | | 1989 | 0.410 | 0.686 | |
| | | 1990 | 0.164 | 0.454 | |
| | | 1991 | 0.201 | 0.472 | |
| | | 1992 | 0.188 | 0.484 | |
| | | 1993 | 0.327 | 0.485 | |
| | | 1994 | 1.097 | 0.415 | |
| | | 1995 | 0.495 | 0.551 | |
| | | 1996 | 0.276 | 0.487 | |
| | | 1997 | 0.600 | 0.546 | |
| | | 1998 | 0.254 | 0.360 | |
| | | 1999 | 0.769 | 0.670 | |
| | | 2000 | 0.430 | 0.382 | |
| SCDNR LL | F-I | 1995 | 741.722 | 0.179 | Yes |
| | | 1996 | 759.202 | 0.119 | |
| | | 1997 | 741.044 | 0.120 | |
| | | 1998 | 942.041 | 0.090 | |
| | | 1999 | 691.181 | 0.108 | |
| | | 2000 | 660.173 | 0.111 | |
| Recreational | F-D | 1981 | 0.0019 | 1.000 | No |
| | | 1982 | 0.0013 | 1.000 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 1983 | 0.0013 | 1.000 | |
| | | 1984 | 0.0009 | 1.000 | |
| | | 1985 | 0.0007 | 1.000 | |
| | | 1986 | 0.0017 | 1.000 | |
| | | 1987 | 0.0019 | 1.000 | |
| | | 1988 | 0.0026 | 1.000 | |
| | | 1989 | 0.0021 | 1.000 | |
| | | 1990 | 0.0021 | 1.000 | |
| | | 1991 | 0.0025 | 1.000 | |
| | | 1992 | 0.0030 | 1.000 | |
| | | 1993 | 0.0023 | 1.000 | |
| | | 1994 | 0.0023 | 1.000 | |
| | | 1995 | 0.0028 | 1.000 | |
| | | 1996 | 0.0019 | 1.000 | |
| | | 1997 | 0.0016 | 1.000 | |
| | | 1998 | 0.0030 | 1.000 | |
| NMFS LL PC | F-I | 1993 | 0.517 | 0.507 | Yes |
| | | 1994 | 0.235 | 0.544 | |
| | | 1995 | 0.343 | 0.483 | |
| | | 1996 | 1.073 | 0.092 | |
| | | 1997 | 0.594 | 0.185 | |
| | | 1998 | 0.439 | 0.378 | |
| | | 1999 | 1.170 | 0.116 | |
| | | 2000 | 0.534 | 0.296 | |
| NMFS GN PC | F-I | 1996 | 5.367 | 0.291 | Yes |
| | | 1997 | 4.013 | 0.344 | |
| | | 1998 | 2.696 | 0.512 | |
| | | 1999 | 5.640 | 0.147 | |
| | | 2000 | 2.747 | 0.314 | |
| | | 2001 | 3.488 | 0.205 | |
| DGNOP | F-D | 1993 | 1.665 | 0.690 | Yes |
| | | 1994 | 2.170 | 0.400 | |
| | | 1995 | 1.982 | 0.590 | |
| | | 1998 | 5.108 | 0.210 | |
| | | 1999 | 4.068 | 0.200 | |
| | | 2000 | 3.083 | 0.280 | |
| | | 2001 | 5.764 | 0.140 | |
| SEAMAP | F-I | 1989 | 345.837 | 0.175 | Yes |
| | | 1990 | 259.675 | 0.154 | |
| | | 1991 | 319.504 | 0.141 | |
| | | 1992 | 328.648 | 0.141 | |
| | | 1993 | 241.345 | 0.157 | |
| | | 1994 | 240.301 | 0.175 | |
| | | 1995 | 302.293 | 0.144 | |
| | | 1996 | 231.672 | 0.162 | |
| | | 1997 | 534.964 | 0.117 | |
| | | 1998 | 334.644 | 0.136 | |
| | | 1999 | 306.455 | 0.146 | |
| | | 2000 | 457.360 | 0.125 | |
| | | 2001 | 489.034 | 0.119 | |
| VIMS | F-I | 1974 | 14.603 | 2.163 | Yes |
| | | 1975 | 11.701 | 1.348 | |
| | | 1976 | 1.994 | 6.069 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 1977 | 16.041 | 0.883 | |
| | | 1980 | 10.937 | 0.592 | |
| | | 1981 | 12.017 | 0.503 | |
| | | 1983 | 7.196 | 1.540 | |
| | | 1987 | 11.769 | 1.477 | |
| | | 1988 | 4.811 | 2.153 | |
| | | 1989 | 1.947 | 3.270 | |
| | | 1990 | 6.301 | 0.671 | |
| | | 1991 | 4.916 | 0.936 | |
| | | 1992 | 6.729 | 0.700 | |
| | | 1993 | 7.601 | 0.777 | |
| | | 1995 | 11.719 | 0.478 | |
| | | 1996 | 9.640 | 0.577 | |
| | | 1997 | 5.221 | 0.883 | |
| | | 1998 | 9.107 | 0.534 | |
| | | 1999 | 12.555 | 0.530 | |
| | | 2000 | 4.635 | 0.885 | |
| | | 2001 | 10.843 | 0.575 | |
| NEFSC Bottom Trawl | | 1968 | 30.067 | 1.035 | Yes |
| | | 1969 | 19.309 | 0.698 | |
| | | 1970 | 19.231 | 1.135 | |
| | | 1971 | 41.049 | 1.04 | |
| | | 1972 | 21.623 | 0.702 | |
| | | 1973 | 41.655 | 0.676 | |
| | | 1974 | 54.496 | 0.438 | |
| | | 1975 | 104.290 | 0.517 | |
| | | 1976 | 48.966 | 0.584 | |
| | | 1977 | 52.707 | 0.302 | |
| | | 1978 | 21.403 | 0.253 | |
| | | 1979 | 20.616 | 0.267 | |
| | | 1980 | 51.460 | 0.172 | |
| | | 1981 | 21.628 | 0.333 | |
| | | 1982 | 14.643 | 0.387 | |
| | | 1983 | 13.149 | 0.412 | |
| | | 1984 | 12.973 | 0.611 | |
| | | 1985 | 17.663 | 0.688 | |
| | | 1986 | 21.186 | 0.543 | |
| | | 1987 | 37.576 | 0.404 | |
| | | 1988 | 9.323 | 0.796 | |
| | | 1989 | 13.347 | 0.654 | |
| | | 1990 | 18.135 | 0.514 | |
| | | 1991 | 10.888 | 0.679 | |
| | | 1992 | 15.685 | 0.668 | |
| | | 1993 | 12.893 | 0.57 | |
| | | 1994 | 4.273 | 1.503 | |
| | | 1995 | 11.823 | 0.598 | |
| | | 1996 | 7.967 | 0.86 | |
| | | 1997 | 33.149 | 0.383 | |
| | | 1998 | 32.709 | 0.458 | |
| | | 1999 | 16.419 | 0.632 | |
| | | 2000 | 25.736 | 1.000 | |
| | | | | | |
| | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Atlantic sharpnose shark** | | | | | |
| Oregon II | F-I | 1972 | 0.400 | 0.341 | Yes |
| | | 1973 | 0.409 | 0.255 | |
| | | 1974 | 1.693 | 0.194 | |
| | | 1975 | 1.283 | 0.178 | |
| | | 1976 | 1.213 | 0.151 | |
| | | 1977 | 0.632 | 0.200 | |
| | | 1978 | 0.686 | 0.204 | |
| | | 1979 | 0.798 | 0.208 | |
| | | 1980 | 1.334 | 0.210 | |
| | | 1981 | 0.845 | 0.235 | |
| | | 1982 | 0.889 | 0.210 | |
| | | 1983 | 0.727 | 0.249 | |
| | | 1984 | 0.663 | 0.365 | |
| | | 1985 | 1.034 | 0.355 | |
| | | 1986 | 0.300 | 0.562 | |
| | | 1987 | 4.655 | 0.911 | |
| | | 1988 | 0.219 | 0.403 | |
| | | 1989 | 0.410 | 0.686 | |
| | | 1990 | 0.109 | 0.529 | |
| | | 1991 | 0.188 | 0.492 | |
| | | 1992 | 0.188 | 0.484 | |
| | | 1993 | 0.278 | 0.517 | |
| | | 1994 | 1.082 | 0.421 | |
| | | 1995 | 0.477 | 0.572 | |
| | | 1996 | 0.229 | 0.577 | |
| | | 1997 | 0.600 | 0.546 | |
| | | 1998 | 0.185 | 0.458 | |
| | | 1999 | 0.769 | 0.670 | |
| | | 2000 | 0.430 | 0.382 | |
| SCDNR LL | F-I | 1995 | 634.652 | 0.187 | Yes |
| | | 1996 | 675.063 | 0.122 | |
| | | 1997 | 686.043 | 0.124 | |
| | | 1998 | 869.921 | 0.094 | |
| | | 1999 | 633.247 | 0.113 | |
| | | 2000 | 565.009 | 0.121 | |
| NMFS LL NE | F-I | 1986 | 0.650 | 0.365 | No |
| | | 1989 | 0.054 | 0.173 | |
| | | 1991 | 0.164 | 0.297 | |
| | | 1996 | 0.015 | 0.212 | |
| | | 1998 | 0.071 | 0.356 | |
| | | 2001 | 0.216 | 0.276 | |
| Recreational | F-D | 1981 | 0.0010 | 1.000 | No |
| | | 1982 | 0.0008 | 1.000 | |
| | | 1983 | 0.0007 | 1.000 | |
| | | 1984 | 0.0006 | 1.000 | |
| | | 1985 | 0.0003 | 1.000 | |
| | | 1986 | 0.0006 | 1.000 | |
| | | 1987 | 0.0009 | 1.000 | |
| | | 1988 | 0.0014 | 1.000 | |
| | | 1989 | 0.0012 | 1.000 | |
| | | 1990 | 0.0010 | 1.000 | |
| | | 1991 | 0.0023 | 1.000 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 1992 | 0.0021 | 1.000 | |
| | | 1993 | 0.0014 | 1.000 | |
| | | 1994 | 0.0017 | 1.000 | |
| | | 1995 | 0.0022 | 1.000 | |
| | | 1996 | 0.0013 | 1.000 | |
| | | 1997 | 0.0011 | 1.000 | |
| | | 1998 | 0.0023 | 1.000 | |
| NMFS LL SE ATL | F-I | 1995 | 2.356 | 0.201 | Yes |
| | | 1996 | 0.561 | 0.309 | |
| | | 1997 | 4.446 | 0.168 | |
| | | 2000 | 5.654 | 0.100 | |
| NMFS LL SE EGM | F-I | 1995 | 0.282 | 0.367 | Yes |
| | | 1996 | 0.214 | 0.516 | |
| | | 1997 | 0.515 | 0.413 | |
| | | 1999 | 0.053 | 0.567 | |
| | | 2000 | 0.651 | 0.471 | |
| NMFS LL SE WGM | F-I | 1995 | 3.209 | 0.226 | Yes |
| | | 1996 | 5.881 | 0.225 | |
| | | 1997 | 2.689 | 0.175 | |
| | | 1999 | 4.500 | 0.160 | |
| | | 2000 | 6.784 | 0.148 | |
| NMFS LL PC | F-I | 1993 | 0.481 | 0.516 | Yes |
| | | 1994 | 0.136 | 0.882 | |
| | | 1995 | 0.301 | 0.520 | |
| | | 1996 | 0.951 | 0.098 | |
| | | 1997 | 0.531 | 0.196 | |
| | | 1998 | 0.380 | 0.413 | |
| | | 1999 | 1.160 | 0.111 | |
| | | 2000 | 0.445 | 0.337 | |
| NMFS GN PC | F-I | 1996 | 2.469 | 0.508 | Yes |
| | | 1997 | 1.676 | 0.654 | |
| | | 1998 | 1.764 | 0.678 | |
| | | 1999 | 3.642 | 0.190 | |
| | | 2000 | 1.631 | 0.450 | |
| | | 2001 | 1.632 | 0.359 | |
| DGNOP | F-D | 1993 | 0.878 | 1.250 | Yes |
| | | 1994 | 1.763 | 0.490 | |
| | | 1995 | 1.524 | 0.730 | |
| | | 1998 | 7.107 | 0.150 | |
| | | 1999 | 2.553 | 0.330 | |
| | | 2000 | 1.882 | 0.460 | |
| | | 2001 | 3.887 | 0.210 | |
| SEAMAP | F-I | 1989 | 333.590 | 0.179 | Yes |
| | | 1990 | 252.386 | 0.156 | |
| | | 1991 | 333.257 | 0.140 | |
| | | 1992 | 297.641 | 0.147 | |
| | | 1993 | 218.216 | 0.164 | |
| | | 1994 | 198.180 | 0.187 | |
| | | 1995 | 280.882 | 0.148 | |
| | | 1996 | 212.855 | 0.169 | |
| | | 1997 | 508.326 | 0.120 | |
| | | 1998 | 279.108 | 0.147 | |
| | | 1999 | 283.205 | 0.151 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 2000 | 437.902 | 0.128 | |
| | | 2001 | 442.492 | 0.126 | |
| VIMS | F-I | 1974 | 14.606 | 2.185 | Yes |
| | | 1975 | 11.694 | 1.363 | |
| | | 1976 | 1.994 | 6.172 | |
| | | 1977 | 16.045 | 0.891 | |
| | | 1980 | 10.790 | 0.602 | |
| | | 1981 | 12.014 | 0.508 | |
| | | 1983 | 7.198 | 1.560 | |
| | | 1987 | 11.772 | 1.492 | |
| | | 1988 | 4.812 | 2.185 | |
| | | 1989 | 1.947 | 3.325 | |
| | | 1990 | 6.300 | 0.680 | |
| | | 1991 | 4.917 | 0.950 | |
| | | 1992 | 6.731 | 0.710 | |
| | | 1993 | 7.603 | 0.787 | |
| | | 1995 | 11.501 | 0.487 | |
| | | 1996 | 9.636 | 0.584 | |
| | | 1997 | 5.221 | 0.896 | |
| | | 1998 | 9.102 | 0.541 | |
| | | 1999 | 12.380 | 0.539 | |
| | | 2000 | 4.633 | 0.898 | |
| | | 2001 | 10.836 | 0.580 | |
| NEFSC Bottom Trawl | F-I | 1974 | 93.232 | 0.958 | Yes |
| | | 1978 | 41.896 | 0.266 | |
| | | 1979 | 36.132 | 0.296 | |
| | | 1980 | 56.482 | 0.242 | |
| | | 1981 | 34.386 | 0.412 | |
| | | 1982 | 19.533 | 0.49 | |
| | | 1983 | 31.479 | 0.396 | |
| | | 1984 | 24.817 | 1.016 | |
| | | 1985 | 18.544 | 1.888 | |
| | | 1987 | 90.891 | 0.54 | |
| | | 1988 | 10.551 | 1.214 | |
| | | 1989 | 20.517 | 0.925 | |
| | | 1990 | 29.974 | 0.888 | |
| | | 1991 | 23.317 | 0.97 | |
| | | 1992 | 32.184 | 0.94 | |
| | | 1993 | 21.193 | 0.717 | |
| | | 1994 | 4.456 | 2.414 | |
| | | 1995 | 38.514 | 0.551 | |
| | | 1996 | 21.627 | 0.864 | |
| | | 1997 | 114.379 | 0.425 | |
| | | 1998 | 57.563 | 0.917 | |
| | | 2000 | 89.508 | 1.000 | |
| | | | | | |
| **Bonnethead** | | | | | |
| Recreational | F-D | 1981 | 0.0009 | 1.000 | No |
| | | 1982 | 0.0005 | 1.000 | |
| | | 1983 | 0.0004 | 1.000 | |
| | | 1984 | 0.0002 | 1.000 | |
| | | 1985 | 0.0004 | 1.000 | |
| | | 1986 | 0.0009 | 1.000 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 1987 | 0.0006 | 1.000 | |
| | | 1988 | 0.0006 | 1.000 | |
| | | 1989 | 0.0008 | 1.000 | |
| | | 1990 | 0.0010 | 1.000 | |
| | | 1991 | 0.0002 | 1.000 | |
| | | 1992 | 0.0006 | 1.000 | |
| | | 1993 | 0.0005 | 1.000 | |
| | | 1994 | 0.0004 | 1.000 | |
| | | 1995 | 0.0005 | 1.000 | |
| | | 1996 | 0.0004 | 1.000 | |
| | | 1997 | 0.0002 | 1.000 | |
| | | 1998 | 0.0005 | 1.000 | |
| NMFS GN PC | F-I | 1996 | 1.534 | 0.387 | Yes |
| | | 1997 | 1.022 | 0.495 | |
| | | 1998 | 0.575 | 0.880 | |
| | | 1999 | 1.617 | 0.184 | |
| | | 2000 | 0.305 | 1.000 | |
| | | 2001 | 1.155 | 0.219 | |
| DGNOP | F-D | 1993 | 0.454 | 2.490 | Yes |
| | | 1994 | 0.562 | 1.620 | |
| | | 1995 | 0.375 | 3.120 | |
| | | 1998 | 0.634 | 1.680 | |
| | | 1999 | 0.705 | 1.210 | |
| | | 2000 | 0.520 | 1.680 | |
| | | 2001 | 0.549 | 1.520 | |
| SEAMAP | F-I | 1989 | 116.746 | 0.330 | Yes |
| | | 1990 | 137.380 | 0.209 | |
| | | 1991 | 221.505 | 0.177 | |
| | | 1992 | 118.300 | 0.198 | |
| | | 1993 | 76.141 | 0.246 | |
| | | 1994 | 204.176 | 0.198 | |
| | | 1995 | 140.176 | 0.190 | |
| | | 1996 | 45.234 | 0.298 | |
| | | 1997 | 145.242 | 0.205 | |
| | | 1998 | 79.315 | 0.242 | |
| | | 1999 | 81.077 | 0.231 | |
| | | 2000 | 168.132 | 0.186 | |
| | | 2001 | 249.260 | 0.156 | |
| | | | | | |
| **Blacknose shark** | | | | | |
| Recreational | F-D | 1981 | 0.0000000 | 1.000 | No |
| | | 1982 | 0.0000000 | 1.000 | |
| | | 1983 | 0.0002171 | 1.000 | |
| | | 1984 | 0.0000146 | 1.000 | |
| | | 1985 | 0.0000340 | 1.000 | |
| | | 1986 | 0.0000536 | 1.000 | |
| | | 1987 | 0.0002788 | 1.000 | |
| | | 1988 | 0.0002632 | 1.000 | |
| | | 1989 | 0.0000353 | 1.000 | |
| | | 1990 | 0.0000710 | 1.000 | |
| | | 1991 | 0.0000001 | 1.000 | |
| | | 1992 | 0.0000958 | 1.000 | |
| | | 1993 | 0.0000528 | 1.000 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 1994 | 0.0002354 | 1.000 | |
| | | 1995 | 0.0000482 | 1.000 | |
| | | 1996 | 0.0002032 | 1.000 | |
| | | 1997 | 0.0001695 | 1.000 | |
| | | 1998 | 0.0001871 | 1.000 | |
| NMFS LL SE EGM | F-I | 1995 | 0.282 | 0.486 | Yes |
| | | 1996 | 0.262 | 0.433 | |
| | | 1997 | 0.515 | 0.202 | |
| | | 1999 | 0.386 | 0.281 | |
| | | 2000 | 0.698 | 0.451 | |
| NMFS LL SE WGM | F-I | 1995 | 0.163 | 0.405 | Yes |
| | | 1996 | 0.690 | 0.371 | |
| | | 1997 | 0.388 | 0.341 | |
| | | 1999 | 0.490 | 0.243 | |
| | | 2000 | 0.608 | 0.232 | |
| NMFS LL PC | F-I | 1993 | 0.008 | 6.171 | Yes |
| | | 1994 | 0.076 | 0.282 | |
| | | 1995 | 0.021 | 1.332 | |
| | | 1996 | 0.000 | 1.000 | |
| | | 1997 | 0.017 | 1.201 | |
| | | 1998 | 0.032 | 0.981 | |
| | | 1999 | 0.052 | 0.493 | |
| | | 2000 | 0.096 | 0.294 | |
| NMFS GN PC | F-I | 1996 | 0.328 | 0.417 | Yes |
| | | 1997 | 0.077 | 1.677 | |
| | | 1998 | 0.137 | 0.881 | |
| | | 1999 | 0.220 | 0.319 | |
| | | 2000 | 0.000 | 1.000 | |
| | | 2001 | 0.082 | 0.741 | |
| DGNOP | F-D | 1993 | 0.466 | 2.070 | Yes |
| | | 1994 | 0.620 | 1.340 | |
| | | 1995 | 0.327 | 3.020 | |
| | | 1998 | 0.372 | 2.500 | |
| | | 1999 | 0.678 | 1.170 | |
| | | 2000 | 0.561 | 1.430 | |
| | | 2001 | 0.608 | 1.290 | |
| | | | | | |
| **Finetooth shark** | | | | | |
| Recreational | F-D | 1981 | 0.0000000 | 1.000 | No |
| | | 1982 | 0.0000000 | 1.000 | |
| | | 1983 | 0.0000000 | 1.000 | |
| | | 1984 | 0.0000000 | 1.000 | |
| | | 1985 | 0.0000000 | 1.000 | |
| | | 1986 | 0.0001916 | 1.000 | |
| | | 1987 | 0.0000003 | 1.000 | |
| | | 1988 | 0.0003763 | 1.000 | |
| | | 1989 | 0.0000031 | 1.000 | |
| | | 1990 | 0.0000011 | 1.000 | |
| | | 1991 | 0.0000086 | 1.000 | |
| | | 1992 | 0.0001718 | 1.000 | |
| | | 1993 | 0.0003231 | 1.000 | |
| | | 1994 | 0.0000545 | 1.000 | |
| | | 1995 | 0.0000201 | 1.000 | |

| | | | | | |
|---|---|---|---|---|---|
| | | 1996 | 0.0000276 | 1.000 | |
| | | 1997 | 0.0000754 | 1.000 | |
| | | 1998 | 0.0000025 | 1.000 | |
| NMFS LL SE WGM | F-I | 1995 | 0.09302 | 1.00000 | Yes |
| | | 1997 | 0.00971 | 1.00000 | |
| | | 1999 | 0.25962 | 0.53930 | |
| NMFS LL PC | F-I | 1993 | 0.01434 | 3.924 | Yes |
| | | 1994 | 0.04574 | 0.610 | |
| | | 1995 | 0.01220 | 2.759 | |
| | | 1996 | 0.12299 | 0.182 | |
| | | 1997 | 0.05715 | 0.425 | |
| | | 1998 | 0.00550 | 6.800 | |
| | | 1999 | 0.01033 | 2.972 | |
| | | 2000 | 0.00010 | 1.000 | |
| NMFS GN PC | F-I | 1996 | 0.899 | 0.430 | Yes |
| | | 1997 | 1.239 | 0.276 | |
| | | 1998 | 0.220 | 1.599 | |
| | | 1999 | 0.756 | 0.262 | |
| | | 2000 | 0.390 | 1.000 | |
| | | 2001 | 0.772 | 0.221 | |
| DGNOP | F-D | 1993 | 0.347 | 2.950 | Yes |
| | | 1994 | 0.293 | 2.810 | |
| | | 1995 | 0.282 | 3.370 | |
| | | 1998 | 0.373 | 2.120 | |
| | | 1999 | 0.385 | 2.140 | |
| | | 2000 | 0.388 | 2.120 | |
| | | 2001 | 0.394 | 1.950 | |
| | | | | | |

**Appendix 2.** WINBUGS code for the state-space Bayesian Surplus Production Model using the Gibbs sampler applied to the small coastal shark aggregate.

```
WinBugs Code
# Small coastal sharks, file is called scs_9series_abs
# Bayesian Surplus Production Model (Meyer and Millar 1999 CJFAS 56:1078-1086)
# units are millions of pounds dressed weight
# this program uses 9 series, not scaled

model scs_9series_abs
{

# Prior distributions

iK ~ dunif(1.609,5.0106)
K <- exp(iK)
#assuming mean for r is 0.07 and SD is 0.2
r ~ dlnorm(-2.659,25.0)

iqOregon ~ dgamma(0.001,0.001)I(0.1,1000)
qOregon <- 1/iqOregon
iqRec ~ dgamma(0.001,0.001)I(0.1,1000)
qRec <- 1/iqRec
iqLlpc ~ dgamma(0.001,0.001)I(0.1,1000)
qLlpc <- 1/iqLlpc
iqGnpc ~ dgamma(0.001,0.001)I(0.1,1000)
qGnpc <- 1/iqGnpc
iqScll ~ dgamma(0.001,0.001)I(0.1,1000)
qScll <- 1/iqScll
iqSeamap ~ dgamma(0.001,0.001)I(0.1,1000)
qSeamap <- 1/iqSeamap
iqDGNOP ~ dgamma(0.001,0.001)I(0.1,1000)
qDGNOP <- 1/iqDGNOP
iqVIMS ~ dgamma(0.001,0.001)I(0.1,1000)
qVIMS <- 1/iqVIMS
iqWHOLE ~ dgamma(0.001,0.001)I(0.1,1000)
qWHOLE <- 1/iqWHOLE

isigma2 ~ dgamma(4.0,0.01)
sigma2 <- 1/isigma2

itau2Oregon ~ dgamma(2.0,0.1)
tau2Oregon <- 1/itau2Oregon
itau2Rec ~ dgamma(2.0,0.1)
tau2Rec <- 1/itau2Rec
itau2Llpc ~ dgamma(2.0,0.1)
tau2Llpc <- 1/itau2Llpc
itau2Gnpc ~ dgamma(2.0,0.1)
tau2Gnpc <- 1/itau2Gnpc
itau2Scll ~ dgamma(2.0,0.1)
tau2Scll <- 1/itau2Scll
itau2Seamap ~ dgamma(2.0,0.1)
tau2Seamap <- 1/itau2Seamap
itau2DGNOP ~ dgamma(2.0,0.1)
tau2DGNOP <- 1/itau2DGNOP
```

```
itau2VIMS ~ dgamma(2.0,0.1)
tau2VIMS <- 1/itau2VIMS
itau2WHOLE ~ dgamma(2.0,0.1)
tau2WHOLE <- 1/itau2WHOLE

P72 ~ dlnorm(0.0,25.0)

# compute P, which is B expressed as a proportion of K each year

Pmean[1] <- log(P72)
P[1] ~ dlnorm(Pmean[1],isigma2)I(0.001,3)
for (i in 2:29){
Pmean[i] <- log(max(P[i-1]+r*P[i-1]*(1-P[i-1])-C[i-1]/K,0.0001))
P[i] ~ dlnorm(Pmean[i],isigma2)I(0.0001,3)
}

# indices

# Oregon
for (i in 1:29){
	ImeanOregon[i] <- log(qOregon*K*P[i])
	IOregon[i] ~ dlnorm(ImeanOregon[i],itau2Oregon)
	residOregon[i] <- IOregon[i]-qOregon*K*P[i]
	}

# Rec
for (i in 1:18){
	ImeanRec[i] <- log(qRec*K*P[i+9])
	IRec[i] ~ dlnorm(ImeanRec[i],itau2Rec)
	residRec[i] <- IRec[i]-qRec*K*P[i+9]
	}

# Llpc
for (i in 1:8){
	ImeanLlpc[i] <- log(qLlpc*K*P[i+21])
	ILlpc[i] ~ dlnorm(ImeanLlpc[i],itau2Llpc)
	residLlpc[i] <- ILlpc[i]-qLlpc*K*P[i+21]
	}

# Gnpc
for (i in 1:5){
	ImeanGnpc[i] <- log(qGnpc*K*P[i+24])
	IGnpc[i] ~ dlnorm(ImeanGnpc[i],itau2Gnpc)
	residGnpc[i] <- IGnpc[i]-qGnpc*K*P[i+24]
	}

# Scll
for (i in 1:6){
	ImeanScll[i] <- log(qScll*K*P[i+23])
	IScll[i] ~ dlnorm(ImeanScll[i],itau2Scll)
	residScll[i] <- IScll[i]-qScll*K*P[i+23]
	}

# Seamap
for (i in 1:12){
	ImeanSeamap[i] <- log(qSeamap*K*P[i+17])
```

```
		ISeamap[i] ~ dlnorm(ImeanSeamap[i],itau2Seamap)
		residSeamap[i] <- ISeamap[i]-qSeamap*K*P[i+17]
		}

# DGNOP
# Position of missing data in DATA section is ignored (NA)
for (i in 1:N1){
		ImeanDGNOP[i] <- log(qDGNOP*K*P[i+21])
		IDGNOP[i] ~ dlnorm(ImeanDGNOP[i],itau2DGNOP)
		residDGNOP[i] <- IDGNOP[i]-qDGNOP*K*P[i+21]
		}
for (i in N2:N3){
		ImeanDGNOP[i] <- log(qDGNOP*K*P[i+21])
		IDGNOP[i] ~ dlnorm(ImeanDGNOP[i],itau2DGNOP)
		residDGNOP[i] <- IDGNOP[i]-qDGNOP*K*P[i+21]
		}

# VIMS
for (i in 1:N4){
		ImeanVIMS[i] <- log(qVIMS*K*P[i+2])
		IVIMS[i] ~ dlnorm(ImeanVIMS[i],itau2VIMS)
		residVIMS[i] <- IVIMS[i]-qVIMS*K*P[i+2]
		}
for (i in N5:N6){
		ImeanVIMS[i] <- log(qVIMS*K*P[i+2])
		IVIMS[i] ~ dlnorm(ImeanVIMS[i],itau2VIMS)
		residVIMS[i] <- IVIMS[i]-qVIMS*K*P[i+2]
  }
for (i in N7:N7){
		ImeanVIMS[i] <- log(qVIMS*K*P[i+2])
		IVIMS[i] ~ dlnorm(ImeanVIMS[i],itau2VIMS)
		residVIMS[i] <- IVIMS[i]-qVIMS*K*P[i+2]
		}
for (i in N8:N9){
		ImeanVIMS[i] <- log(qVIMS*K*P[i+2])
		IVIMS[i] ~ dlnorm(ImeanVIMS[i],itau2VIMS)
		residVIMS[i] <- IVIMS[i]-qVIMS*K*P[i+2]
		}
for (i in N10:N11){
		ImeanVIMS[i] <- log(qVIMS*K*P[i+2])
		IVIMS[i] ~ dlnorm(ImeanVIMS[i],itau2VIMS)
		residVIMS[i] <- IVIMS[i]-qVIMS*K*P[i+2]
		}

# WHOLE
for (i in 1:29){
		ImeanWHOLE[i] <- log(qWHOLE*K*P[i])
		IWHOLE[i] ~ dlnorm(ImeanWHOLE[i],itau2WHOLE)
		residWHOLE[i] <- IWHOLE[i]-qWHOLE*K*P[i]
		}

# management parameters

MSY <- r*K/4
FMSY <- r/2
BMSY <- K/2
```

```
P2001 <- P[29]+r*P[29]*(1-P[29]) -C[29]/K
B2001 <- P2001*K
B01ratio <- B2001/K

for (i in 1:29){
B[i] <- P[i]*K
F[i] <- C[i]/B[i]
Fratio[i] <- F[i]/FMSY
Bratio[i] <- B[i]/BMSY
}
}
# end model

Inits 1

list(
P=c(0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5),
r=0.04,
iK=2.996,
iqOregon=10,iqRec=10,iqLlpc=10,iqGnpc=10,iqScll=10,iqSeamap=10,iqDGNOP=10,iqVIMS=10,iqWHOLE=10,
isigma2=100,
itau2Oregon=100,itau2Rec=100,itau2Llpc=100,itau2Gnpc=100,itau2Scll=100,itau2Seamap=100,itau2DGNOP=100
,
itau2VIMS=100,itau2WHOLE=100,
P72=0.5)

Inits 2

list(
P=c(1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0),
r=0.04,
iK=2.996,
iqOregon=10,iqRec=10,iqLlpc=10,iqGnpc=10,iqScll=10,iqSeamap=10,iqDGNOP=10,iqVIMS=10,iqWHOLE=10,
isigma2=100,
itau2Oregon=100,itau2Rec=100,itau2Llpc=100,itau2Gnpc=100,itau2Scll=100,itau2Seamap=100,itau2DGNOP=100
,itau2VIMS=100,itau2WHOLE=100,
P72=1.0)


Data
# Note that the time series used here are not scaled (i.e., they are not divided by the mean)
list(
C=c(1.500000,1.579500,1.899000,1.997000,2.208500,2.142000,2.155500,2.753500,2.436000,2.145370,2.326693,2.
329138,1.586167,1.871510,2.460620,3.391646,2.673374,2.470417,2.302710,2.638232,3.901423,5.735617,2.63979
5,3.372593,3.450388,3.890826,3.549619,2.261834,2.238344),

IOregon=c(0.57,1.01,1.99,1.54,1.61,0.91,0.80,0.99,1.45,0.88,0.95,0.79,0.66,1.07,1.07,4.66,0.27,0.41,0.16,0.20,0.19,
0.33,1.10,0.50,0.28,0.60,0.25,0.77,0.43),
IRec=c(0.0019,0.0013,0.0013,0.0009,0.0007,0.0017,0.0019,0.0026,0.0021,0.0021,0.0025,0.0030,0.0023,0.0023,0.0
028,0.0019,0.0016,0.0030),
ILlpc=c(0.5167,0.2346,0.3430,1.0734,0.5945,0.4392,1.1699,0.5342),
IGnpc=c(5.3670,4.0130,2.6960,5.6400,2.7470),
IScll=c(741.722,759.202,741.044,942.041,691.181,660.173),
ISeamap=c(345.837,259.675,319.504,328.648,241.345,240.301,302.293,231.672,534.964,334.644,306.455,457.360
),
IDGNOP=c(1.665,2.170,1.982,NA,NA,5.108,4.068,3.083),
```

```
IVIMS=c(14.603,11.701,1.994,16.041,NA,NA,10.937,12.017,NA,7.196,NA,NA,NA,11.769,4.811,
1.947,6.301,4.916,6.729,7.601,NA,11.719,9.640,5.221,9.107,12.555,4.635),
IWHOLE=c(21.623,41.655,54.496,104.290,48.966,52.707,21.403,20.616,51.460,21.628,14.643,13.149,12.973,17.6
63,21.186,37.576,9.323,13.347,18.135,10.888,15.685,12.893,4.273,11.823,7.967,33.149,32.709,16.419,25.736),
N1=3,N2=6,N3=8,
N4=4,N5=7,N6=8,N7=10,N8=14,N9=20,N10=22,N11=27)
)
```