# Status of Gag in the Gulf of Mexico, Assessment 3.0

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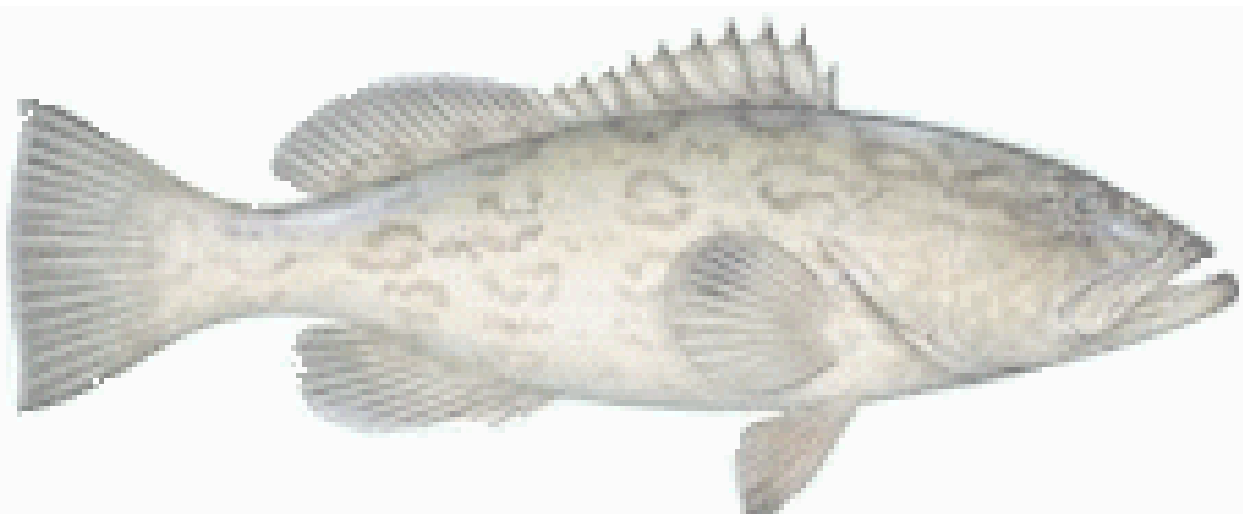

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## 1. Introduction

The status of gag, *Micteroperca microlepis*, in the Gulf of Mexico was reviewed using information on landings and discards from 1986 primarily through 1999, size composition, size at age and catch rate information from multiple recreational and commercial fisheries. The general approaches used in previous assessments (Schirripa and Goodyear 1994 and Schirripa and Legault 1997) were followed in developing the catch history, the catch-at-size and the catch-at-age using a stochastic ageing method (Goodyear 1997). An additional catch-at-age derived from observed age composition (Fitzhugh *et al.* 2001) was developed by Cummings and Parrack (in prep). The data of Fitzhugh *et al.* were also used to develop a preliminary version of a revised growth curve. Additional emphasis was placed on development of indices of abundance.

### 1.1 Management history

Management actions that may have influenced the fisheries for gag and that could have an impact on the data used in examining the historical status of the stock include bag limits and size limits. A 20" (51 cm) minimum size became effective in February 1990, and a grouper bag limit of five groupers became effective in April of 1990. On June 19, 2000 the minimum size for landings was raised to 22" (56 cm) for recreational catches and to 24" for commercial landings. At the same time, sales of gag were prohibited from February 15 through March 15, and two marine reserves in which fishing for reef fish and bottom oriented species was prohibited year round, were established.

## 2. Biology

### 2.1 Species Identification

Historically gag often has been confused with black grouper, *Micteroperca bonaci* (Hoese and Moore, 1977, Bullock and Smith, 1991). In the 1994 assessment (Schirripa and Goodyear 1994) this problem was addressed by combining gag and black grouper catches and catch rates from areas where black were thought to be rare or absent, and by estimating fractions of the combined catch thought to be gag. Generally they restricted catch rate analyses to regions thought to have zero or low fractions of black grouper in the catch. The same approach was used in the 1997 assessment (Schirripa and Legault 1997)
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Additionally, gag have, at times, been included in commercial landing statistics as unclassified grouper; prior to 1986 all grouper landings were recorded as unclassified grouper, and the majority of them were considered to have been red grouper, *Epinephalus moria*.

With some exceptions we have followed a similar approach. The various assumptions about species composition are explained in detail in the appropriate sections on catch and catch rates. We have tabulated catches of ‘reported’ and ‘calculated’ to make clear the impact of the assumptions about proportions of reported gag, black and unclassified grouper.

### 2.2 Review of Life History

Gag are found from Brazil to New England (Briggs 1958, Smith 1971), with the apparent center of distribution occurring in the eastern Gulf of Mexico (McErlean 1963). Spawning sites occur in association with drowned Pleistocene reefs found at depths of 40-120m over the continental shelf west of Florida, with the preferred areas being at depths of 70-90m (Coleman et al. 1996, Fitzhugh et al. 2000).

The reproductive season begins in November or December and doesn't end until May or June, but most spawning activity takes place in February and March (Hood & Schlieder 1992, Coleman et al. 1996, Collins et al. 1998, Fitzhugh et al 2000). Gag appear to form loose spawning aggregations of 10s to 100s of individuals, and spawning sites may be traditional (Coleman et al. 1996). Larval gag spend 30-70 days drifting as part of the plankton before settling in shallow-water seagrass habitats, often in estuaries (McErlean 1963, Koenig & Coleman 1988, Hood & Schlieder 1992, Coleman et al. 1996, Koenig & Coleman 1998, Heinisch & Fable 1999, Fitzhugh et al. 2000). A recent study found no evidence of regional/latitudinal variation in the duration of the larval period, but, as is typical, did note a large degree of annual variation in recruitment (Fitzhugh et al. 2000). Settlement, which occurs primarily in April and May, is followed by a period of rapid growth, as juvenile gag increase from 20-70mm to 200-300mm in length by late in the year, at which time they depart the nursery habitats (an event referred to as 'egress'), apparently migrating to shelf reef habitats (Moe 1966, Hood & Schlieder 1992, Heinisch & Fable 1999, Koenig & Coleman 1998, Fitzhugh et al. 2000, Johnson & Koenig in press). Some evidence suggests that juveniles settle in relative near-shore, shallow areas and gradually move to deeper habitats as they age and increase in size (Hood & Schlieder 1992). Several studies have examined length-weight-age data and estimated growth rates of adult gag from fisheries data (McErlean & Smith 1964, Collins et al. 1987, Hood & Schlieder 1992, Johnson et al. 1993, Schirripa & Goodyear 1994, Schirripa & Burns 1997). Natural mortality rates appear to be low in the nursery habitats (Koenig & Coleman 1998), but are unknown for juveniles or adults after egress from seagrass habitats. Being protogynous hermaphrodites, gag are females in early life and later transform into males when they are larger. Females mature as early as 2 years of age, over half are mature by 4 years of age, and by 7 years of age, all are mature (Hood & Schlieder 1992). Sex transformation occurs in individuals as young as 5 years of age, but it is not until age 10-11 that the majority of individuals are male (Hood & Schlieder 1992). Virtually all individuals older than 16 years of age are males. Gag are a long-lived species, some males live to ages greater than 20 years (Collins et al. 1987, Hood & Schlieder 1992, Collins et al. 1987). Size appears to reach an asymptote around age 13-15 at approximately 1.0-1.1m and 15-17kg (Hood & Schlieder 1992, Schirripa & Goodyear 1994). Without fishing it is likely much larger and older individuals would be found in the population. Coleman *et al.* (1996) suggested that selective fishing that results in higher fishing pressure on larger individuals coupled with protogynous hermaphrodism would make this species especially vulnerable to recruitment overfishing (Coleman *et al.* 1996). Estimates of the sex ratio in this population from various time periods have indicated a large decrease in the proportion of males in the population to the point where it is feared that reproductive output may be limited by a scarcity of reproductive males (Coleman *et al.* 1996). Limited data suggest that females first reproduce at approximately 57-71 cm length, or 3-5 years old and that most males are reproductively mature following transformation, thus males first reproduce at 7 years of age when they are about 85 cm in length. Female gag appear to spawn repeatedly during the spawning season at intervals of a few days (Collins et al. 1998). Spawning frequency appears to vary considerably among years. As females age they spawn more frequently and their batch fecundity increases as their length (and weight) increase, thus producing an exponential increase in estimated annual fecundity, at least for females up to the age of eight (Collins et al. 1998).

## 2.3 *Age Compositon and Growth*

Fitzhugh *et al.* (2001) presented an analysis of age composition of commercial and recreational fisheries from 1991-2000. They noted evidence of strong and weak year-classes which could be followed over multiple years, but found no evidence of differences in size at age between such year-classes. They noted gear and sector (recreational and commercial) differences in age composition, which they attributed to depth related differences in availability and, in part, to differences in areas of exploitation (northern and southern regions of the west Florida shelf). They considered the apparent variation in year-class strength to be primarily due to variation in recruitment.

This information was used to examine growth (Calay *et al.* in prep), to develop age-length keys (Cummings *et al.* in prep) and to estimate the age composition of the catch using methods similar to those used for SEFSC mackerel stock assessments (Cummings and Parrack in prep). Size at age from 1992-2000 was provided by SEFSC, Panama City

2.3.1. *Growth*

This section is summarized from Cass-Calay *et al.* (in prep).

Length-at-age data from SEFSC, Panama City were obtained from the recreational and commercial fisheries, and from scientific surveys and tournaments. However, due to the limited number of samples, scientific survey and tournament data were excluded from analysis of growth. To model the growth of gag, von Bertalanffy growth equations were fit to length-at-age data using least squares nonlinear regression.

2.3.1.1 Recreational

Three types of vessels participate in the recreational fishery in the Gulf of Mexico: charter boats, head boats and private boats. Cass-Calay *et al.* (in prep) fit von Bertalanffy growth equations to the length-at-age data from each vessel type to examine the effects of vessel type on the growth of gag grouper (Figure 1). Lengths are in mm. The von Bertalanffy equations fit to the recreational data are as follows.

**Charter:** $TL = 2431.0(1\text{-}exp^{-0.0340(Age\ +\ 5.671)})$ n = 859, $r^2 = 0.590$, $p << 0.001$

**Head Boat:** $TL = 1711.6(1\text{-}exp^{-0.0570(Age\ +\ 4.708)})$ n = 107, $r^2 = 0.660$, $p << 0.001$

**Private:** $TL = 2869.9(1\text{-}exp^{-0.0334(Age\ +\ 3.591)})$ n = 37, $r^2 = 0.792$, $p << 0.001$

All the regression equations were significant, however, the solution for the private boat data was considered unreliable due to the limited number of data points and their distribution over ages. The three regression equations were quite similar (Figure 1D), especially over the common range of the data (Age = 2-10). This result indicated little difference in selectivity among vessel types with respect to overall size at age of gag. Therefore, the data were combined, and a single regression equation was calculated for the recreational data. The combined von Bertalanffy equation is given below. It should be noted that the combined data set included additional data points that were not identified by vessel type.

**All Recreational:** $TL = 2071.3(1\text{-}exp^{-0.0479(Age\ +\ 4.119)})$ n = 1466, $r^2 = 0.644$, $p << 0.001$

2.3.1.2 Commercial

Commercial samples were collected using two gear types: handlines and longlines. Cass-Calay *et al.* (in prep) fit Von Bertalanffy growth equations to the handline and longline data (Figure 2). Those equations were:

**Handline:** $TL = 1394.9(1\text{-}exp^{-0.1003(Age + 2.755)})$ n = 1446, $r^2 = 0.730$, $p << 0.001$

**Longline:** $TL = 1292.9(1\text{-}exp^{-0.1279(Age + 2.418)})$ n = 542, $r^2 = 0.721$, $p << 0.001$

The two regression equations appeared to be similar (Figure 2C), and were not statistically different using a test for coincident regressions (Zar 1984) ($0.05<p<0.10$). Again, for the purposes of modeling gag growth, gear type selectivity appeared to have little influence in the commercial sector. Therefore, the gear types were pooled to create a single commercial data set. The combined von Bertalanffy equation was:

**All Commercial:** $TL = 1331.6(1\text{-}exp^{-0.1175(Age + 2.257)})$ n = 2000, $r^2 = 0.750$, $p << 0.001$

2.3.1.3 Pooling Recreational and Commercial Data

Finally, Cass-Calay *et al.* (in prep) compared the recreational and commercial growth curves (Figure 3). The curves were found to be statistically different using a test for coincident regressions (Zar 1984) ( $0.01<p<0.05$). which can be interpreted as resulting from selectivity differences between the fishing sectors. However it was thought that the curves were very similar between ages 2 and 10, and very few fish were collected from the recreational fishery that were older than 10 years. Also, the $L_\infty$ value of the recreational growth equation (1745.9) was estimated with very few observations at older ages. With additional sampling, it is expected that the two growth curves would become more similar. Therefore data from the two sectors were combined and a single growth equation representative of all components of the harvested population was fit.

Using the combined recreational and commercial data, Cass-Calay *et al.* (in prep) estimated the von Bertalanffy and inverted von Bertalanffy equations (Figure 4) using least squares nonlinear regression. The equations were as follows.

$TL = 1381.5(1\text{-}exp^{-0.1061(Age + 2.4359)})$ n = 3546, $r^2 = 0.743$, $p << 0.001$

$Age = [ln(1 - TL)/1390.1)/-0.134] - 0.868$ n = 3546, $r^2 = 0.754$, $p << 0.001$

It was noted that there was substantial lack of fit for fish older than age 10. Attempts to improve the fit using a double von Bertalanffy equation and a more complex growth equation that allows k, the growth rate, to change with age (Porch *et al.* in press) were unsuccessful. Further research, perhaps using robust nonlinear regression techniques, should be considered in the future.

2.3.1.3. Conclusions

The combined growth model developed by Cass-Calay *et al.* (in prep) from the 1992-2000 data set provide by SEFSC, Panama City was selected for use as the primary growth model for use in this assessment to replace the model used in the previous assessments. The primary reason for making this change was that the new growth curve was derived from a substantially larger number of observations obtained from a greater number of years. The $L_\infty$ and k estimates from these curves were similar [143.5 and 0.1051 for the model first used by Schirripa and Goodyear (1994) versus 138.2 and 0.1061 for Cass-Calay *et al.* (in prep)]; however the $t_0$'s were quite different (1.3503 Schirrpa and Goodyear versus 2.4359). The two curves predicted different sizes at age for younger gag (Figure 5) and would result in different estimates of age composition calculated using the curves. As noted above, the new growth curve also exhibited lack of fit at the older ages. These concerns suggested that the direct use of the length-at-age information in the assessment model should be investigated for gag.

The new growth model indicated that the average fish grew about 7 cm per year between age 3 and age 6, 5 cm per year between ages 6 and 9, 4 cm per year between ages 9 and 11 and more slowly thereafter. By age 8 the average gag had achieved 67% of its maximum size, 73% by age 10, and 81% by age 13. The observed age composition (Figure 4) suggested a 20-30 cm range of size at age roughly from age 4 to age 13.

## 3. **Catch**

As noted in section 2.1 gag and black grouper have been confused in the catch statistics and gag have been included in 'unclassified grouper' statistics. Grouper catches were first recorded in the landings statistics by species starting in 1986, and, for this reason, 1986 was the earliest year used in the analyses in the previous assessments (Schirripa and Goodyear 1994 and Schirripa and Legault 1997); we have followed the same approach. The previous assessments used a variety of approaches to calculate what was considered the actual gag catch; for instance all black grouper from Texas through Alabama were considered gag, and a large proportion of the combined gag and black grouper catch in Florida was considered gag. To demonstrate the effects of these assumptions, catch data were tabulated for records originally reported as gag in the various data bases (reported gag) and for the catches considered to be gag from reported catches of gag, black grouper and unclassified groupers (calculated gag).

### *3.1 Landings*

#### 3.1.1 Commercial

Commercial landings of gag were estimated from the SEFSC accumulated landings data base for 1986 and later. The accumulated landings data generally have information on capture gear and location for Texas and Louisiana through 1991, Mississippi and Alabama in all years, and for Florida landings for 1997 and later. To calculate the capture gear and location for west Florida landings from 1986-1996, the annual Florida general canvass data were used to calculate patterns of reported catches by gear and fishing location for each year, county and species. Catches from U.S. Gulf of Mexico waters were retained (shrimp grids 2-21 and the portions of grid 1 which did not include some Atlantic waters - 1.1, 741.1 and 748.1). The data from 2000 were considered to be preliminary. In addition, no data were available from Louisiana in most of July and all of August-December 1999, therefore landings for July-December were estimated.

Because of apparent misidentification of gag and black grouper commercial catches throughout the Gulf, the previous assessments used proportions of gag in the combined catches of gag and black grouper to calculate the total catch of gag (Schirripa and Goodyear 1994). For Florida catches, those proportions were primarily based on dockside observations of recreational catches recorded by MRFSS samplers in 1990-1992 (species identification of gag and black grouper by MRFSS samplers prior to 1990 and especially prior to 1989 were considered inaccurate). For Texas to Alabama, and for most Florida counties, it was assumed that all commercial catches were gag. For southwestern Florida (Manatee county and south) it was assumed that decreasing fractions of the commercial catch were gag (Table 1). Those fractions were used for this assessment. It is recommended that these fractions be further investigated.

The proportion of gag (Table 2) in annual Florida landings of all identified groupers (gag, red grouper, black grouper, marbled grouper, nassau grouper, yellowfin grouper, yellowmouth grouper, scamp, yellowedge grouper, misty grouper, speckled hind, rock hind, red hind and snowy grouper) was multiplied times the unclassified grouper catch to estimate the part of that unclassified catch which was gag. Catches only from Gulf of Mexico waters were included. Landings of black grouper from Texas through Alabama were all assumed to be gag. During 1986-1990 Gulf-wide unclassified grouper landings by U.S. vessels ranged from about 109,000 lb to about 318,000 lb; during 1991-1995 they ranged from about 14,000 to about 52,000 lb, and from 1996 through 1999 they were less than 10,000 lb.

The July-December 1999 landings for Louisiana were estimated, because they had been partially reported for July and not reported for August-December. Monthly proportions of Louisiana annual landings showed higher proportions of gag landed in February-April in 1998- 2000 than in 1994-1997. Therefore the annual proportion of the combined catches from July-December in 1998 and 2000 was calculated and multiplied times the 1999 January - June landings to estimate the July-December 1999 landings for Lousiiana.

Annual landings and average weights are generally recorded in the data bases as whole weight in pounds. The gutted to whole weight conversion factor used for groupers in creating the landings data bases was considered inaccurate (Schirippa and Goodyear, 1994). Therefore, landings data were reconverted to gutted weight ( gutted = whole / 1.18). All weight estimates and related statistics (MSY, etc) in this report are reported in gutted weight equivalents.

The calculated commercial landings of gag in gutted weight (Table 3) were between 1.5 million and 1.9 million pounds in all but three years. The lowest on record at about 1.2 million lb was in 1988. The 1998 commercial landings were the highest on record with about 2.5 million lb, the 1999 landings were about 2.0 million lb while the preliminary estimate for the year 2000 is about 1.7 million lb. Handlines (including rod and reel and bandit rigs) accounted for the largest amount of catch during 1986-2000 and longlines accounted for the second largest amount (Table 4 and Figure 6).

Schirippa and Legault (1997) reported landings in gutted weight, and their annual totals were similar to those calculated for this assessment (Table 5). The differences in those statistics between the assessments were due to corrections to the data base (primarily for 1996), small differences between the Florida general canvass data used in the previous assessment and the accumulated landings data used in this assessment, and differences in the treatment of catches reported from some inland counties in Florida and catches from some capture locations.

The calculated landings of gag were more than twice the reported landings of gag during the late 1980's (Figure 2). Since then it appears that dealers have reported the species landed more accurately.

### 3.1.2 Recreational

Recreational catches (landings -A - and discards, both B1 and B2) were obtained from MRFSS (Marine Recreational Fisheries Statistical Survey), headboat (Southeast Fisheries Center Headboat Survey) and Texas Parks and Wildlife data sets for 1986 and later. To address the uncertainties associated with species identification of gag and black grouper, the conventions established for the 1994 assessment (Schirippa and Goodyear 1994) were generally followed; for MRFSS all black grouper from Texas through Alabama and 87% of the combined catch of gag and black grouper in west Florida were considered gag. Headboat catches in west Florida were considered to be accurately identified. To maintain consistency with the treatment of the MRFSS data, all black grouper catches recorded in the headboat and Texas data sets between Texas and Alabama were considered to be gag. Further investigation into these assumptions may be warranted. Gag and black grouper catches taken by vessels from the Florida keys which usually fished in the Atlantic were excluded.

The reported (not including any black grouper) total number of gag landed by recreational fisheries is given in Table 6.

The total calculated recreational landings (including some fish reported as black grouper) ranged from about 200,000 fish to about 700,000 fish with the highest catches in the earliest 3 years (1986-1988) and the latest three years (1997-1999) (Table 7). Florida accounted for the largest fraction of the catch and Texas the smallest. The total estimated yield using average weights from the catch-at-size ranged from 1.4 million lb to 4.0 million lb (Table 8). The MRFSS accounted for the majority of the recreational catches (from about 175,000 to 650,000 fish annually), and the head boat survey accounted for roughly 10,000 to 50,000 fish annually (Table 9).

The amount of black grouper calculated to be gag using the procedure adopted by Schirippa and Goodyear (1994) decreased quite substantially during the late 1980's (Figure 8). In 1998 and 1999 the number of fish reported as gag was larger than the number calculated to be gag. This was probably due to increasing catches of reported gag and decreasing catches of reported black grouper and to the assumption that in Florida 87% of either species was actually gag. It is recommended that alternative methods of assigning species be investigated.

The MRFSS was the only survey with estimates of variance in the landings (including dead discards - type B1 catch). The MRFSS catches and the associated coefficients of variation for Florida are presented in Table 10 by year and wavc; the table was restricted to Florida because the majority of the catches occurred there (Table 7).

### *3. Releases*

Direct estimates of the number of discards was available only for the recreational fisheries covered by the MRFSS. For the other fisheries, ratios of observed, or assumed, number discarded to the observed, or assumed, number retained were used in estimating the total number discarded. To do so, those ratios were multiplied times the calculated number of fish landed at or above the minimum size. In a few instances at-sea observer data were available and were used to calculate the proportion discarded only for the year in which they were taken. However for most fisheries and years observer data were not available, and differences in size composition before and after the imposition of the minimum size in 1990 was used in calculating the proportion of the catch which might have been discarded. The proportion of the 1986-1989 catch which was less than 51 cm (20 in.) was calculated. It was assumed that 1991-1999 catches would have size distributions similar to the 1986-1989 size distribution. The total catch of gag less than 51 cm was calculated by multiplying the number caught which were larger than the size limit, times the proportion less than the size limit from the observer data or the 1986-1989 data. Those proportions were calculated from the 1986-1989 size composition aggregated by month, quarter or year depending on the fishery (commercial gear or recreational mode) being used to assign size to the released catch and the number of 1986-1989 size samples available (see section 5.1).

Following the approach used in previous assessments, it was assumed that 20% of recreational releases died, and 30% of commercial releases died. A higher proportion dead was assumed for the commercial fishery, because commercial catches of gag are thought to occur in deeper water than recreational catches and because release mortality apparently increases with depth.

If any undersized fish were recorded when fish were measured at the dock, they were included in the calculated catch-at-size in the usual manner. It was assumed that those fish (and the estimated total number of such fish in the total catch) would have been discarded dead at sea, but were landed because they were already dead. Therefore the calculated dead discards [(proportion < minimum size) *( number landed > minimum size) * discard mortality rate] was reduced by the calculated number landed less than the minimum size. As a result in some years for some gears no fish were calculated to have been discarded at sea, because the calculated total number landed less than the minimum size equaled or exceeded the calculated number of dead discards.

### 3.2.1 Commercial

SEFSC personnel observed catches taken aboard vessels using traps (Anon. 1995), vessels using bandit rigs (classified as handline in this assessment) and vessels using longlines in late 1994 though late 1995 (Anon. 1995). On the observed trap trips data were recorded from almost 4,000 trap hauls between December 1993 and November 1994; of the 35 gag observed, only 3 were retained and 32 were discarded (a 10.7 ratio of discarded catch to retained catch). The observed bandit rig trips occurred from January-July of 1995 and more than 26,000 drops ('sets') were observed. Fifty seven gag were observed caught, of which 51% were released. The observed longline trips occurred between January 1994 and February 1995; no gag were observed caught on more than 225,000 hooks. It is noted that most of these observations were made in 1994, when most of the fish in the large 1993 year-class would have been below the minimum size. As noted above, these ratios were applied only to the year from which most of the data were reported.

Because observer data were not available for most years, the 1986-1989 size composition was used to estimate the proportions in 1990-1999 which were released. During 1986-1989 about 2.6% of the landed gag which were measured were less than 20 in. (51 cm) for both the handline and the longline fisheries. During those years no trap sizes were recorded so the handline size composition was assumed.

### 3.2.2 Recreational

The number of gag released alive at sea was estimated for the fisheries covered by the MRFSS. Estimates for west Florida-Louisiana are given in Table 11.

Mote Marine Laboratory personnel have recorded data from observed head boat trips in recent years (K. Burns, personal communication) under a MARFIN grant (NA87FF0421) in cooperation with scientists from Florida State University (C. Koenig and F.Coleman). Those data were kindly made available for this assessment and were used to calculate that about 58% of the 43 gag observed in 1999 were less than the minimum size.

The ratio calculated from the 1999 Mote data, was similar to an overall ratio of roughly 55% calculated from the 1986-1989 measured landings.

### 3.3 Total Catch

The calculated number of fish landed and discarded dead by sector (recreational or commercial) is shown in Figure 9 and Table 12, and the corresponding yield is shown in Figure 10 and Table 13.

## 4. Size Composition

The size composition of landings from the various fisheries was reviewed to determine how best to construct catch-at-size and catch-at-age.

### 4.1 Landings

#### 4.1.1 Commercial

The commercial gears exploited overlapping size ranges (Figure11). The spear and trap fisheries exploited the smallest range of sizes of gag (roughly 50-95cm), the handline fishery exploited sizes of roughly 50-210 cm with the highest proportions between 55 and 95 cm, while the longline fishery exploited fish of roughly 65-130 cm with the highest proportions at 70-110 cm.

#### 4.1.2 Recreational

The recreational fisheries had roughly similar size compositions during 1986-1989, when sample sizes were low for some of the fisheries (370 measured from charter boat anglers, 114 from private boat anglers, and 2157 from headboat anglers), and in 1991-2000 (Figure 12, head boat data is only through 1999).

## 5. Catch-at-size and Catch-at-age

For the 1997 assessment catch-at-age and catch-at-size were developed using the same system to assign size composition to catches. Once a size sample was selected, the age composition was estimated by the probabilistic method of Goodyear (1997) (hereafter referred to as the recruitment-and-mortality modulated method, RMM). That approach was followed for this assessment, but the sample selection rules used to assign samples to a catch were somewhat different and the final catch-at-size was retained in fine stratifications (by state, month and gear) to permit contrasting the estimates with those from other methods. In addition an alternative ageing approach, which used an age-length-key and stochastic growth-curve-based method (Cummings and Parrack in prep), was used to estimate age composition from the catch-at-size..

### 5.1. Catch-at-size

The catch-at-size was developed to: (1) use with alternative assessment methods such as estimating catch-at-age from the observed ageing samples or length based methods and (2) calculate the yield (weight of the catch) for fisheries sampled by surveys for which catch was primarily reported in number of fish (MRFSS, Texas Parks and Wildlife).

Size composition samples were assigned to catches based on a hierarchical set of rules. One set of rules was used for recreational landings, another for commercial landings, a third for discards for which observer samples were not available and a fourth for discards from a fishery in a year for which observer data were available. In all cases, size samples were pooled across states. For discards from a stratum (year, commercial gear or recreational mode - shore, head boat, charter, private) from which observed sizes were available, size samples were used if there were at least 5 fish measured. For the remaining types of catches there had to be at least 25 fish measured for a sample to be selected. In all cases the most disaggregated stratum was year, month, and gear or mode and the next level of aggregation was the year, season (3 months long) and gear or mode. For recreational fisheries the third level of aggregation considered was by year, month and all modes pooled, the fourth was year, season and pooled modes and the last was all samples from all recreational fisheries from a year. For the commercial landings, samples were never aggregated across gears, because of the relatively large differences among gears in size composition of the catch (Figure 11). Thus, for the commercial catch-at-size, sample availability was checked first for the month, then the season and then for the entire year for each gear. For discards from years and fisheries without observer coverage, the pooled sizes from 1986-1989 were used to assign size composition and aggregation across gear or mode was permitted depending on the number of samples available. Sample availability was first checked for mode/gear and month, second for mode/gear and season; thirdly for month with modes (recreational) or gears (commercial) combined, fourthly for season and all modes or gears and finally for all samples from the sector. In a small number of instances there were not 25 size measurements within a sector for the entire year for the most aggregated sample assignment stratum considered for that mode or gear. In those instances samples from either of the surrounding two years were used, selecting which ever had the larger number of fish measured.

## 5.2. Catch-at-Age

Catches-at-age were developed using two different approaches. One was the recruitment-and-mortality modulated (RMM) method which uses an index of recruitment (Goodyear 1997), as was done for the previous assessments (Schirripa and Goodyear 1994, Schirripa and Legault 1997). The second was a combined age-length-ley and stochastic growth-curve-based approach (ALK+) similar to methods which have been used for Gulf and Atlantic mackerels for several years (the Mackerel Stock Assessment Panel ageing method); for periods when there were were sufficient observations, age-length-keys were developed, while for periods for which there were not sufficient numbers sampled, a probabilistic method was used (Cummings and Parrack in prep, Shepherd 1985). The probabilistic methods used in the two ageing methods differ. The RMM approach developed by Goodyear (1997) uses a growth curve, an index of recruitment and estimates of fishing and natural mortality to establish the probability that fish is an age given its size and date at capture. The probabilistic component of the age-length-key and stochastic growth-curve-based method (ALK+) involves a statistical search to find the age composition that when combined with the probability of age given length, provides the best fit between observed and expected size composition for a catch (Cummings and Parrack in prep) The growth curve developed by Cass-Calay *et al.* (in prep) was used in almost all probabilistic ageing for this assessment (the one exception was a sensitivity run).

For the assessments the age of the plus group was set at 10. By that age the average gag had achieved about 75% of the average maximum size and growth was slower than at younger ages (see section 2.3.1.3). Also by that age a significant fraction of the population may be male.

### 5.2.1 Ageing with Recruitment-and-Mortality Modulated Method

The catch-at-age was developed using the recruitment-and-mortality modulated (RMM) ageing approach (Goodyear1997) using an index of young-of-the-year abundance from the sea grass trawl survey (Koenig and Coleman 1998) as was done by for the 1997 assessment (Schirripa and Legault 1997). Young-of-the-year indices of abundance were developed by Brown *et al.* (2001) using data provided by Koenig (personnel communication, Florida State University); the index that included the large 1993 year-class (designated 'young of year, with 1993') was selected for use in ageing (see section 6). The procedure requires having an index of recruitment for every year-class in the analysis; for the year classes prior to 1991 (1976-1990); the average catch rate from years without very large young-of-the-year catch rates (1992 and 1994-1999) was used, as was done for the 1997 assessment. The young-of-the-year index used in this assessment differed from the index used in the 1997 assessment in that the 1989 and 1990 values were not estimated from observed annual means for those years, instead the multi-year average was used (see section 6.1 and Figure 13). The same size-sample assignment criteria as were used for creating the catch-at-size were used to create the catch-at-age. The growth curve developed by Cass-Calay *et al.* (in prep) was used (section 2.1.3.2). The standard deviation of length given age estimated from the age-composition data was 0.12. The initial catch-at-age derived from these inputs is shown in Table 14.

The estimated catch-at-age was passed into a VPA along with a young-of-the-year abundance index (only 1991-1999 values were used; no averages of moderate recruitment years were included for earlier years), and additional indices of abundance derived from catch statistics (four additional indices were used in the base case, and two additional indices for some of the sensitivity runs). Subsequently, year-age specific fishing-mortality rates output by the VPA were passed back into the ageing procedure. This process was usually iterated five times (only once or twice for some sensitivity runs), and the results from the last iteration were considered final. For results of these analyses see section 7.

5.2.2 Age-length-key plus Stochastic Growth-Curve-Based Method

Cummings and Parrack (in prep) estimated gag catch-at-age using the method of the Mackerel Stock Assessment Panel from the data provided by SEFSC, Panama City Those data were considered sufficient to develop semi-annual age-length-keys for 1992-1994, January-June 1995, January-June 1996, and 1998-1999 (Cummings *et al.* in prep).For the remaining periods, we employed a stochastic method that consisted of using a statistical search to estimate the catch-at-age for each catch observation in the catch-at-size; deviations between the observed and expected size composition were minimized given the matrix of monthly probability of age from the Cass-Calay *et al*. (in prep) growth equation ad a standard deviation of size-at-age of 0.12 (Cummings and Parrack in prep). The 1999 estimated catch-at-age had no age-1 fish. Because the VPA software had difficulty in calculating a fishing-mortality rate for a catch of zero under some conditions, we replaced the zero with a value of 1. The resulting catch-at-age is shown in Table 15.

## 6. Indices of abundance

Six indices of abundance were developed for this assessment: one from trawl tows over seagrass beds directed at juvenile gag, one each for the handline, longline and trap fisheries, one for the headboat fishery, and one from the MRFSS for charter and private boats combined (Table 16).

6.1. Young-of-the-year Seagrass Tows

Models were fit to the seagrass-tow catch rates using the delta-method approach, assuming a binomial distribution for the proportion positive and a poisson distribution for the positive catch rates (Brown *et al.* 2001). The initial index developed from the data was derived from a model for proportion positive that included fixed-effect terms for year and location, and a random-effect term for a year-location interaction, and a model of positive catch rates that included fixed-effect terms for year, month and location, and random-effect term for year-month and year-location interactions. Apparently because the 1993 sampling occurred at only one location, the model was unable to estimate a standardized mean for 1993. Therefore, a second set of analyses were conducted using only fixed effects (i.e. ignoring the year interactions). In the resulting models of the proportion positive and the positive catch rates the only significant effect was year. When scaled to the 1991 value, the random-effects and the fixed-effects models showed the same pattern, except that the fixed-effects model included an estimate for 1993, which was absent from the random-effects model.

Sea-grass catch rates for 1989 and 1990 were available only as annual aggregates. Therefore, they could not be included in the standardization procedure, and, as a result, the index used in the ageing and tuning algorithms did not include standardized estimates for those years; these years were included in the VPA tuning procedure used in the 1997 assessment (Schirripa and Legault 1997). That index and the one derived for this assessment (included the 1993 value) are contrasted in Figure 13. As noted in section 5.2, for the RMM ageing system used the juvenile-index values as indicators of abundance for each year-class; the fixed effects model including the value for 1993 was used, and the mean of the 1992 and 1994-1999 values was used for 1990 and earlier.

6.2 Commercial Handline, Longline and Trap Indices

Indices of abundance were derived from commercial trip reports included in the Reef Fish Logbook data base (Heinemann 2001a, 2001b and 2001c). In the handline and longline analyses, Heinemann did not find year interactions which met the criteria for inclusion in the model. In the analysis of the trap index a significant year-grid interaction was found in both the proportion positive and the positive catch rates. Because of the complexity of these interactions the trap index was derived from a fixed-effect model excluding these interactions. The handline, longline and trap indices are plotted in Figures 14-16.

6.3 MRFSS Index

An index was developed from the west-Florida sampling of charter and private/rental vessels conducted by MRFSS personnel. Information on targeting was incorporated in the model based on target information recorded during angler interviews, or, if not recorded, from the species composition of the catch. Targets were classified into five groups: gag, reef fish, pelagics and sharks combined, mixed and unknown. A delta model with a binomial error structure for the proportion positives and a log-normal error structure for the positive catch rates was used to develop the index. The final model for the proportion positive included the fixed-effects year, county, area (<10 mi, and > 10 mi), mode (private and charter) and target. The final model for positive catch rates included those same fixed effects and a random year-mode interaction. The resulting index of abundance is shown in Figure 17.

6.4 Headboat Index

An index of abundance was derived using a generalized-linear-model. Again, the delta-method approach was employed with a binomial error structure for the proportion positive and a poisson error structure for the positive catch rates (Brown 2001). The number of gag landed per angler hour was used as the measure of catch rates on trips which landed gag. The three zones in the eastern Gulf of Mexico were used in the analysis. The final proportion positive model included the fixed-effects year, month, vessel-within-zone and trip (half-day, three-quarter-day, full-day and multi-day). The final model of positive catch rates included the fixed effects year, month and vessel-within-zone. The standardized catch rates are shown in Figure 18.

**7. Current Status, VPAs**

VPAs were conducted on catches-at-age derived using (1) the recruitment-and-mortality modulated (RMM) approach of Goodyear (1997), which was used in previous gag assessments, or (2) the age-length-key plus stochastic growth-curve-based (ALK+) approach developed by Cummings and Parrack (in prep), using data provided by SEFSC, Panama City The VPAs were similar to those used in the ADAPT approach (Powers and Restrepo 1992), with modifications added to provide greater flexibility in 1) the calculation/estimation of the fishing-mortality rates in the most recent year, 2) the fishing-mortality rates on the oldest ages in earlier years, and 3) the catchability coefficients (Porch 1999a).

The VPA analyses were conducted using one of two assumptions about the selectivity associated with the fishery dependent indices of abundance. For one set of analyses, the selectivity associated with each index was assumed to be constant over years. For the second set, the selectivity was assumed to vary annually. In assessments of other species, the year-constant selectivity has consistently provided better fits to the data (Porch personal communication, Turner *et al.* 2000), because it eliminates conflicting assumptions about catchability and selectivity. Nevertheless year-variable selectivity was considered here, because patterns in fishing-mortality rates estimated in the VPAs using the RMM catch-at-age under the constant index selectivity assumption indicated that very large year classes were less heavily exploited than less abundant year classes; thus, as those large year classes moved through the fishery, estimated selectivity at age changed from year to year (see section 7.1.2).

A summary of the four sets of VPA runs (two catches-at-age by two selectivity assumptios), and some additional runs, is provided in Table 17. One set of additional runs contrasted the effects of the different growth curves used in this assessment and the previous assessments. Additionally for each of the two catch-at-age types, and the two assumptions about index selectivity, two sensitivity runs were made (recruitment and commercial indices, and recruitment and recreational indices). For the ALK+

analyses with year constant index selectivity, an additional sensitivity analysis investigated the effects of assuming that selectivity in 1999 was the same for ages 6 years and older.

The natural mortality rate was assumed to be 0.15 in all models.

Unless otherwise noted, the fishing-mortality rates on ages 2, 4, 6, and 8 in the terminal year were estimated in the model. Based on assumptions made in the previous assessment, the fishing-mortality rates for other ages were based on assumed relationships to estimated values, as follows: age(0) = 0.05*age(2), age(1) = 0.10*age(2), age(3) = age(4), age(5) = age(6), and age(7) = age(8) = age(9). The fishing-mortality rate on the plus group (age 10 and greater) was set equal to the fishing-mortality rate on age 9.

All VPAs used the young-of-the-year index with the 1993 value estimated (Table 16, year-only model). Additionally, unless otherwise noted, four other indices were included: handline, longline, MRFSS and headboat. The trap index was not included because of the presence of significant year interactions, and because of possible effects of trap saturation.

For examination of results, abundances were tabulated for age 0, ages 1-4, 5-9 and 10+, and abundance-weighted average fishing-mortality rates were tabulated for ages 1-4, 5-9 and 10+. Ages 1-4 represent ages of fish with little or no reproductive output, ages 5-9 represent ages with substantial egg production, and ages 10+ should include some reproductive females and most of the reproductive males. Estimated abundances and fishing-mortality rates are shown in the tables only for year classes which recruited in 1996 and earlier, and through 1997 for ages 1-4 in the figures. These restrictions were used because the most recent year-class strengths, and the fishing-mortality rates on those year classes, typically were estimated with very high uncertainty and potential bias.

## 7.1. Recruitment-and-Mortality Modulated Catch-at-Age VPAs

These analyses were conducted using the recruitment-and-mortality modulated (RMM) approach used in previous assessments. The approach incorporates expected abundances, which are derived from a recruitment index and total mortality rates (Goodyear 1997). For most analyses, RMM procedure was iterated 5 times, and at that point the VPA results were considered final. If fewer than 5 iterations were performed, the number of iterations is stated.

### 7.1.1 Effect of different growth equations.

Catch-at-age was generated using the growth equation developed in the previous assessment and the one developed for this assessment (Cass-Calay *et al.* in prep). Both recruitment-and-mortality-mortality-ageing procedures used all five indices, and were run for one iteration. The catch-at-age estimated using the growth equation developed by Cass-Calay *et al.* is presented in Table 15, and the catch-at-age estimated using the growth equation from the 1994 and 1997 assessments is presented in Table 18. For most years, the estimated catch-at-age for age x from the equation developed by Cass-Calay *et al.* was of similar magnitude to the catch-at-age for age x+1 estimated using the equation used in the earlier assessments. The differences in estimated fishing-mortality rates are shown in Figure 19.

The patterns in fishing mortality are similar, although the growth curve from this assessment suggests higher mortality rates for the 5-9 and 10+ age classes.

### 7.1.2 Constant Index Selectivity

The RMM ageing was iterated five times with all five indices of abundance. The estimated catch-at-age from iteration 5 is presented in Table 19. The estimated catch of age 0 ranged from about 150,000 to about 350,000 fish per year, with values below 200,000 fish before 1993 and above that level thereafter. Estimated catches of ages 1-4 declined from about 700,000 fish annually in the mid-late 1980s to less than 300,000 fish in 1990, and then increased to about 800,000 annually in the mid- to late-1990s. Estimated catches of ages 10+ were estimated to be 5-8,000 fish annually in the period 1986-1995, with higher levels in the earlier part of that period; estimated catches then declined to less than 1,000 fish annually in 1998 and 1999.

The estimated abundances and fishing-mortality rates are presented in Tables 20 and 21, respectively. The selectivity patterns for each index of abundance (Figure 20) indicate that the MRFSS fisheries, dominated primarily by the private boat catch, exploited the youngest age composition, followed by the headboat fishery, the handline fishery and then the longline fishery. The fits to the indices of abundance are shown in Figure 21. The fit to the young-of-the-year index was much poorer than any of the other four indices, despite the inclusion of the index in the ageing phase. Neither of indices from the recreational fisheries were fit well in 1991-1994; the MRFSS index was poorly fit during the late 1990's.  The indices from the commercial fisheries, which covered fewer years than those from the recreational fisheries, did not have residual runs for as many years as did the indices from the recreational fisheries.   The summarized abundance estimates are shown in Figure 22, and the fishing-mortality rates in Figure 23. The estimated age-0 abundances showed three strong year classes in the early- to mid-1990s (1991, 1993 and 1996), with year classes from other years ranging from roughly 10% to 30% of the size of the 1993 year class. The abundance of 10+ gag was estimated to be relatively constant in 1986-1991, and then decreased until 1998-2000 when its estimates again relatively constant. Fishing-mortality rates were estimated to be generally higher on 5-9 and 10+ age groups than on 1-4 year olds. Estimated fishing-mortality rates on 1-4 year olds appeared to decrease in years when the larger year classes were age 1. Fishing mortality on ages 5-9 was estimated to have increased from the mid- to late-1980s to the mid-1990s, and then to have decreased.

The estimated fishing-mortality rates showed year-class effects (Table 21), particularly for age 3 and older. For instance, the fishing-mortality rate on the 1994 year class was substantially larger than the fishing-mortality rate on the 1993 year class in 1994-1998. Similarly, the fishing-mortality rate on the 1989 year class was larger than the fishing-mortality rate on the 1990 year class in 1990-1998. Such patterns suggested that the assumption of year-constant selectivity of indices of abundance might not be correct, and, therefore, year-variable index selectivity analyses were conducted (see section 7.1.3).

#### 7.1.2.1 Sensitivity Runs

Because of the differences in fits between indices from the recreational and commercial fisheries, two sensitivity analyses were conducted to further investigate this feature – one with the commercial indices alone, which emphasized older ages, and another with recreational indices only, which emphasized younger ages. The young-of-the-year index was used in both sensitivity trials. The ageing procedures with each set of indices were iterated two times.

The analysis with the commercial indices had better fits to all three indices in the earlier parts of the time period (Figure 24), and a very different pattern of fishing-mortality rates compared to the base case (Figure 25). These results indicate that the current fishery has virtually no effect on the stock, and that the highest recruitment was on the order of 40 times larger than the smallest, unlike the prior run, which showed roughly a 10-fold range in year-class strength. This result is attributed to the estimation of two very large year classes (1993 and 1991), which were subsequently estimated to have reached the fishery, and are now entering into the plus group.

The run using the two indices from recreational fisheries had what appeared to be better fits to the MRFSS index in the most recent years, and the in earliest years. There was little change in the quality of the fits to the juvenile index, and a slight degradation in the fit to the headboat index (Figure 26). The estimated fishing-mortality rates were lower than in the runs with all indices (Figure 27).

7.1.3 Year Variable Index Selectivity

The catch-at-age derived with the RMM method, which used the recruitment index and mortality rates estimated from VPAs using year-variable index selectivity, is shown in Table 22. In general, the catch-at-age was similar to the catch-at-age estimated assuming year-constant index selectivity, although the 1998 and 1999 estimated recruitments were somewhat lower. However, the estimated catches of individual year classes aged 2-6 in 1999 were different between the year-constant and year-variable index selectivity runs – the 1997 year class showed a 30% increase, the 1996 year class a 55% decrease, the 1995 year class a 70% decrease, and the 1993 year class a 50% increase. The fits to the indices(Figure 28) were similar to those under the year-constant index selectivity assumption, although, in general, not quite as tight. The estimated abundance and fishing-mortality rates are presented in Tables 23 and 24, and are summarized in Figures 29 and 30, respectively. The estimated fishing-mortality rates in 1999 on ages 6 and 8 were 0.016 and 0.041, values substantially below the estimates from the run assuming year-constant selectivity (Table 21). The estimated recruitment of the 1993 year class (more than 50 million fish) was 10 times larger than the next largest year class (1991), and roughly 50-80 times larger than the remaining year classes (Table 22). The estimated fishing-mortality rates were somewhat lower than the fishing-mortality rates estimated under the year-constant index selectivity assumption through about 1991, then they declined to near zero by the late 1990s.

The Akaike Information Criteria (AIC) from the VPA assuming the year-variable index selectivity was substantially larger than the AIC from the VPA with the year-constant index selectivity assumption (Table 17), indicating that the model with the year-constant assumption was more parsimonious.

7.1.3.1 Sensitivity Runs

The estimated fishing-mortality rates from both the recreational-only and commercial-only runs were unrealistically low for the older ages – less than 0.02 for ages 5 and older in the recreational analysis and for ages 3 and older in the commercial analysis (Table 17).

### 7.2 Age-Length-Key plus Stochastic growth-curve-based Catch-at-age

These analyses used the catch-at-age developed by Cummings and Parrack (in prep) based on the age-composition data provided by SEFSC, Panama City  It was anticipated that the VPA might have difficulty finding a solution with the catch of one fish at age 1 in 1999 (changed from 0 to 1, see section 5.2.2), and, therefore, it was decided to estimate 1999 fishing-mortality rates for both ages 0 and 1 in addition to ages 2, 4, 6 and 8, as was done for the RMM catch-at-age developed using the recruitment index and fishing mortality estimates.

The catch-at-age estimated with the ALK+  method differed in many respects from the catches-at-age estimated with the recruitment-and-mortality-modulated method. Catches of age 0 were estimated to be less than 10,000 fish before 1992, and less 65,000 fish later, compared to hundreds of thousands of fish estimated by the other approach. Catches of ages 1-4 were roughly 100,000 fish higher in 1986-1988, declined to about the same level as the recritment-and-mortality-modulated catch-at-age in 1990, and, thereafter, were roughly 100-200,000 fish higher in most years. Catches of ages 5-9 were often 50-100,000 fish higher in this catch-at-age than in the RMM catches-at-age. Catches of ages 10+ were estimated to be roughly 15-25,000 fish annually in the 1986-1988, and since have ranged from about 6-14,000 fish, differing from the alternative catch-at-age in the 1986-1988 levels and the 1998 and 1999 levels.

#### 7.2.1 Constant Index Selectivity

The selectivity patterns for each index of abundance (Figure 31) indicated that exploitation was primarily on  4-8 year olds in contrast to the selectivities estimated from the RMM catch-at-age (Figure 20) which indicated high exploitation rates by at least one gear on the 1-10+ age groups. Additonally in contrast to the RMM catch-at-age, the age with the highest selectivity was older for the recreational fisheries with the ALK+ catch-at-age, and the age with the highest selectivity was younger for the commercial fisheries. These estimated selectivity patterns all indicated that ages 9 and older were less vulnerable to fishing than younger ages. The reliability of that estimate will depend on the quality of the ageing data.  Cummings (pers comm) has indicated low confidence in age-length-key estimates for ages over age 8, but a higher level of confidence in the stochastic ageing until age 15. It should be noted that the commercial index selectivity patterns were derived primarily with age-length-key estimates (1992-1994, January-June in 1995 and 1996, and 1998-1999), while the recreational index selectivity patterns are based on catches-at-age estimated with both components of this ageing approach (ALK+). The lower selectivity patterns for the 9 and 10+ groups might result in greater uncertainty about the estimates of abundance for those ages.

The fits to the indices are shown in Figure 32. AS would be expected, the fit to the trawl-survey index was much worse than in the VPAs run with the recruitment-and-mortality catch-at-age calibrated to that index, while the fits to the fishery dependent indices were generally tighter.

The estimated abundances and fishing-mortality rates derived using the ALK+ catch-at-age and the constant index selectivity assumption are given in Tables 25 and 26, and are summarized in Figures 33 and 34. The estimated recruitment patterns were less variable than those estimated using the recruitment modulated catch-at-age (Figures 22 and 30). In addition, the 1991 and 1993 year classes were estimated to be smaller and more similar to the surrounding year classes. The abundances of the 1-4 and 5-9 year old groups were estimated to be about twice as large as with the alternative catch-at-age. The changes in abundance of the 10+ group were completely different – much higher 1986 abundances followed by an increase (approximately 300%) during 1990-2000, compared to a decline (85%) during 1991-1998 in the analysis under the alternative catch-at-age. Fishing-mortality rates were estimated to be generally below 0.2, substantially less than with the RMM catch-at-age, and the fishing-mortality rates on 10+ gag were estimated to be quite low (Figure 34).

7.2.1.1 Sensitivity Analyses

7.2.1.1.1 Sector Specific Sensitivity Analyses

The estimated fishing-mortality rates from the sensitivity runs using the young-of-the-year and the recreational indices had fishing-mortality rates similar to those from the run with all four indices (Table 17). In contrast, the estimated fishing-mortality rates were higher for most ages, especially age 4.

7.2.1.1.2 Uniform Selectivity on Older Ages

The decrease in index selectivity at the older ages (Figure 31) was considered questionable, because large changes in selectivity among age groups of similar average sizes may be unlikely in the presence of fisheries which exploit the larger fish in a population. Therefore additional analyses to explore alternative assumptions about selectivity on older ages were conducted. If the selectivities were equal for the oldest ages and if the estimated fishing-mortality rates for age-8 fish were greater than the 0.012 (for the analysis just described in section 7.2.1), then a more realistic abundance pattern might be estimated. In the primary analyses for ALK+ catch-at-age, the 1999 fishing-mortality rates on ages 0, 1, 2, 4, 6, and 8 years were estimated. For the sensitivity analysis, the 1999 fishing-mortality rates on ages 0, 1, 2, 4, and 6 years were estimated; the fishing-mortality rates for ages 5 and 7-9 were set equal to that for age 6. The estimated fishing-mortality rates were substantially higher on age 4 and on age 6 (Table 17). The associated fits are shown in Figure 35. Estimated abundances and fishing-mortality rates are given in Tables 27 and 28, and are summarized in Figures 36 and 37, respectively.

7.2.2 Year Variable Index Selectivity

The AIC from the analysis assuming year-variable index selectivity was about 20% higher than in the analysis with the year-constant index selectivity assumption, indicating that the year-constant assumption provided a more parsimonious explanation of the data (Table 17).

The abundances and fishing-mortality rates estimated with the ALK+ catch-at-age and year-variable index selectivity are presented in Tables 29 and 30, and are summarized in Figures 39 and 40. The estimated levels of recruitment were more variable and somewhat smaller that in the corresponding analysis with year-constant index selectivity (Figure 33). The estimated abundances of ages 1-4 increased in a similar pattern, but to lower levels, while the 5-9 year olds were at roughly similar levels in 2000 as in 1986 in the variable-selectivity case, but were roughly 2.5 times higher in 2000 than in 1986 in the constant-selectivity analysis. The abundances of ages 10+ in the year-variable analysis increased about 50% between 1986 and 2000, while in the year-constant analysis that group increased to about 4 times its initial levels.

#### 7.2.2.1 Sensitivity Analyses

The estimated fishing-mortality rates from the analysis with the young-of-the-year index and the recreational indices were substantially lower than the estimates from the analysis with all five indices (estimates for ages 2, 4 and 6 roughly one third lower; Table 17). In contrast, the estimates from the analysis with the young-of-the-year index and the commercial indices generally were 2-3 times larger than in the analysis with all five indices.

### 7.3 Overview of VPA Results

The catches-at-age used for the two sets of analyses differed. The recruitment-and-mortality-modulated catches-at-age indicated larger catches of age 0 and lower catches of age 1-4 and 5-9; the ALK+ catch-at-age had higher catches of ages 10+ in the earlier and later years (Tables 15, 22 and 25).

The estimated fishing-mortality rates in 1999 from the RMM catches-at-age were higher on age 2 and lower for age 4 (Table 17). In the year-constant selectivity analyses the selectivity patterns differed between the two catches-at-age (Figures 20 and 31).

Substantial increases occurred in all catch rates in all fisheries from the late 1980s/early-1990s to late-1990s. The catches (landings plus dead discards) did not necessarily match this patterns. Recreational catches were relatively high in the mid- to late-1980s, low in the early-1990s, and increased rapidly thereafter (Figure 9). That pattern was matched in the headboat, but not MRFSS, catch rates; the latter were at their lowest in the mid- to late-1980s and increased by 2-3 times in the early-1990s (Table 16). Commercial catches roughly doubled from the late-1980s/early-1990s to the late-1990s, whereas the commercial catch rates increased to 4-5 times over the early-1990s levels by the late-1990s. These differences in patterns between catches and catch rates can make it difficult for the VPAs to find solutions.

A wide range of fishing-mortality rates and associated abundances were estimated, and, therefore, there is uncertainty in the current (1999) status of gag in the Gulf of Mexico. Some of the estimates may be unrealistic based on what might be considered very large changes in abundance. For example, in the analysis using a catch-at-age derived with the ALK+ method under the assumption of constant-index selectivity when ages 0, 1, 2, 4, 6, and 8 were estimated, the age 10+ abundances were estimated to have increased approximately 4 times over 1986 level. Likewise, in the analysis using the RMM catch-at-age with year-variable index selectivity, the number of recruits from the 1993 year class was estimated to be roughly 50 times larger than most other year classes.

7.4 Comments and Recommendations Concerning VPAs

Both catches-at-age would have been impacted by the uncertainty in the size composition of the discarded catch (section 5.1). The discarded recreational catch represents roughly 40-50% of the total estimated number of fish killed in recent years (Figure 9). Size samples from discards were available from only a few years and gears; sizes less than 51 cm TL from 1986-1989 were almost always assumed to represent the size composition of discards since size limits were imposed. Additional at-sea sampling of kept and released fish, such as is being conducted at the Mote Marine Lab under a MARFIN contract, is needed.

The apparent selectivity of the commercial gears in the ALK+ analyses decreased above age 7 (gag average 90 cm at age 7.5 years), which was unexpected especially for the longline fishery which historically caught fish to 120 cm (on average 16 years old at 120 cm). From examination of the age-composition data, Cummings (pers. comm.) recommended using an 8+ group rather than a 10+ group with the catches-at-age estimated from an age-length-key, and suggested that the decrease in selectivity above age 8 could be associated with low numbers of fish sampled at age for those ages. In the future, alternative plus groups should be considered.

Imprecision and inaccuracies in the young-of-the-year index used in estimating the catch-at-age with the RMM catch-at-age could have resulted in inaccuracies in the estimated catches-at-age. There were no standardized estimates of recruitment for many of the year classes (1976-1990; a mean from years of moderate recruitment was used), and in order to include the 1993 year class an index without year interactions had to be used. Additionally, Fitzhugh *et al.* (2001) indicated that the 1996 year class appeared to be large, while the recruitment index indicated that it was only of moderate size, suggesting great imprecision if the age composition data is considered a reliable indicator of year class strength. The impact of using the mean of all observed catch rates, rather than the mean of catch rates from moderate years should be investigated.

In the future, if the recruitment-and-mortality modulated (RMM) ageing approach is to be used, consideration should be given to incorporating the ageing and assessment phases in the same routine so that a simultaneous solution for all parameters could be obtained in a statistical modeling approach.

It is also recommended that statistical estimation systems which assume error in catches and other inputs be considered.

The terminal year parameters estimated for this assessment were initially limited to fishing-mortality rates for ages 2, 4, 6 and 8 years, based on the selection of an assessment from 1997 (Schirripa and Legault 1997) by the Reef Fish Stock Assessment Panel. Some deviations from estimating those ages were investigated because of data limitations or for sensitivity analyses. It is recommended that in the future consideration be given to investigating other combinations of terminal year parameters.

## 8. Management Reference Points and Projections

Management reference points were calculated from the deterministic VPA results given a modified selectivity vector which attempted to account for recent management actions and two contrasting assumptions about possible stock-recruitment relationships. Bootstrapping was used to estimate the uncertainty about the deterministic results, and to provide an indication of bias in the estimates. Projections were conducted for possible use in estimating the impacts of various landings scenarios in the short term, and possible recovery times in the longer term.

Two of the VPAs from the four catch-at-age and index-selectivity combinations produced estimates of 1996-2000 stock sizes that were considered more likely than others to reflect stock status; namely the VPA using the recruitment-and-mortality modulated (RMM) catch-at-age with the year-constant selectivity assumption (section 7.1.2), and the VPA using the ALK+ catch-at-age with the year-variable index selectivity assumption (section 7.2.2). The VPA which used the RMM catch-at-age with the year-variable selectivity assumption (section 7.1.3) was considered unrealistic because of the estimated size of the 1993 recruitment (Figure 29). The VPA using the ALK+ catch-at-age with the year-constant index selectivity assumption (section 7.2.1) was considered unrealistic because of the rate of increase in the size of the 10+ group throughout the period, and its estimated size in 2000 (Figure 33). To provide information on the possible effects of assuming that the selectivity on the oldest ages was equal to that on ages 5 and 6 for the ALK+ catch-at-age with the year constant index selectivity assumption, reference points and projected stock sizes were calculated for the sensitivity case described in section 7.2.1.1.2. It is suggested that before the reference-point information from that sensitivity analysis be used for management, further exploration of the effects of estimating fishing-mortality rates for additional ages in 1999, and the effects of alternative plus group assumptions, should be conducted.

Gag grouper is a protogynous hermaphrodite, which means that females change to males. Generally the largest fish are males, and, as such, may be especially vulnerable to fishing. Because gag change sex the status of both the male and female portions of the population may be of concern to managers. Therefore, the status of both female and male reproductive condition in the Gulf of Mexico was calculated. For females, reproductive condition was measured in terms of total female gonad weight for the proportion of the population above 56 cm (22") using the model preferred by the Reef Fish Assessment Panel from the 1997 assessment. That metric was the product of the number of fish at age, the proportion female at age, and the truncated (56 cm and larger) gonad weight at age (Figure 41). Male reproductive condition was estimated as the product of numbers at age, the proportion male at age, male maturity at age (derived from Hood and Schlieder, 1992), and weight at age (Figure 42). Males age 7 and below were assumed to be immature, 75% of 8 and 9 year-old males were assumed to be mature, and all males age 10 and older were assumed to be mature.

Reference points needed for defining the current (1999) status of gag in the Gulf of Mexico were estimated based on the results of the various VPA analyses. The fishing-mortality rate that produces a 30% spawning potential ratio ($SPR_{30\%}$) was used as the proxy for the fishing-mortality rate at MSY (maximum sustainable yield), and the fishing-mortality rate that produces a 40% spawning potential ratio ($SPR_{40\%}$) was used as the proxy for OY (optimum yield). Because the female reproductive-potential function reaches a maximum at age 8, long-term fishing at $F_{30\%}$ and $F_{40\%}$ will generally result in the relatively low biomass levels of males. The combination of the female reproductive function and the assumed selectivity pattern (see below) results in estimates of $F_{30\%}$ and $F_{40\%}$ which are much higher (about 2-3 times) than the assumed natural mortality rate. Because males are older; maximizing male biomass would require a lower fishing-mortality rate. A bench mark that maximizes the yield from the entire population, given estimated recruitments, is $F_{max}$, the fishing mortality rate at which yield per recruit is maximized. Because of gag growth patterns and the female reproductive characteristics, $F_{max}$ is lower than both $F_{30\%}$ and $F_{40\%}$. The obvious implication here is that larger long term yields could be obtained at fishing mortality levels lower than $F_{30\%}$ and $F_{40\%}$. $F_{max}$ was selected as an additional reference fishing-mortality rate to provide some measure of the effects of lower fishing rates on both female and male gag.

A stock-recruitment relationship is needed to estimate potential yields such as the MSY and OY proxies. The estimated spawning-stock sizes and recruitments from the deterministic runs from each of the two VPAs in which fishing-mortality rates for ages 2, 4, 6 and 8 in 1999 were estimated are shown in Figures 43and 44, and for the sensitivity run on the ALK+ catch-at-age using year variable index selectivity in which ages 0, 1, 2,4 and 6 were estimated in Figure 45. The stock-recruitment estimates from the RMM catch-at-age showed little indication that recruitment was influenced by stock biomass over the range estimated, while with the analyses of ALK+ catch-at-age, there was some indication of increasing recruitment with spawning stock. The small number of spawning stock sized and recruitment observations, and their general distributions, suggested that it would not be possible to estimate reasonable Beverton and Holt stock-recruitment equations. Two hockey-stick stock-recruitment relationships, similar to those described by Barrowman and Meyers (2000) were examined for each set of VPAs. In one stock-recruit relationship, projected recruitment was assumed to equal the 1986-1996 geometric mean recruitment with recruitments below the minimum observed spawning-stock biomass assumed to decrease linearly to zero. The second stock recruitment relationship assumed that recruitment would increase linearly from zero to the highest spawning stock size observed along a linear regression slope fit to the observed data, and above the maximum observed spawning stock size, recruitment would equal the amount predicted by the regression at the maximum. For all analyses, recruitment was assumed to have a log-normal distribution with a standard deviation of 0.3.

Projections to 2012 were conducted to determine the time in might take for spawning-stock biomass to achieve the minimum spawning-stock size threshold, the yield associated with various fishing-mortality rate reference levels, as well as the mortality rates associated with possible future yield levels. Historical and predicted future yields and yield-per-recruit statistics under the various scenarios projected were in landed weight (estimated yield of discards was not included); however projected dead discards were accounted for in the calculations.

Recruitment estimates in the latest years of VPAs are often highly uncertain. Therefore, for each boot-strapped VPA, the 1997 through 1999 recruitments were replaced with estimates from the spawning stock-recruitment relationship and that year's estimated spawning-stock size. In those years, the associated fishing-mortality rates were recalculated to be consistent with the substituted levels of year class strength.

The selectivity pattern used in calculating the reference points, and in the projections, was derived from the geometric means of the estimated fishing-mortality rates for 1997-1999 for each bootstrap and then further modified to try to account for the effects of new size regulations that went into effect in 2000. While several of the fishing-mortality rates in 1999 were externally fixed rather than having been estimated in the VPAs, the 1997-1999 period was selected for calculating the geometric means, because at least in some of the deterministic VPAs the estimated fishing-mortality rates were changing rapidly during that period. The new size limits raised the minimum size from 51 to 56 cm for recreational landings, and to 61 cm for commercial landings. Fish of 51 cm were assumed to be 1 year old, and fish of 52-60 cm were assumed to be 2 years old. The numbers landed in each of those ages during 1997-1999 were tabulated by sector from the catch-at-size. The number that would not have died was calculated assuming 80% survival for the recreational sector, and 70% for the commercial sector (sensitivity to those survival rates has not been investigated). The proportionate reduction in the total number killed was then calculated for each year, and the geometric mean of the annual values (about 0.05 for age 1, and 0.65 for age 2) was used to reduce the selectivity in the year 2000 and beyond.

For the projections, the removals in 2000 were calculated to be 5.4 million pounds including dead discards. The preliminary estimate of commercial landings was 1.7 million pounds. For the MRFSS, the A+B1 catches and the B2 catches were 544,188 fish and 1,306,024 fish respectively; as with the VPA inputs, 20% of the B2s were assumed to have died. The commercial discards, the headboat landings and the headboat discards were calculated from the geometric means of the 1997-1999 catches in numbers of fish. The yields from the MRFSS and headboat landings were calculated using the geometric means of the 1997-1999 average weights.

The uncertainty in current (1999) management reference points and their bias, as well as projected stock sizes along with their associated uncertainty, were estimated from 500 bootstraps of the VPAs. For bootstrapping, the residuals for each index were rescaled by their calculated variance and non-parametrically resampled (Porch 1999b). Bias is expected in non-linear modeling when limited numbers of observations are used to estimate relatively large numbers of parameters. The degree of bias may be an indicator of the ability of the model to provide meaningful information. There is debate about whether to correct estimates for bias in part because there is uncertainty in the estimate of the bias (Efron and Tibshirian 1993).

Both uncorrected and bias-corrected estimates are provided. The bias in the deterministic estimate was assumed equal to the difference between the bootstrap median and the deterministic estimate. Bias correction was attempted by subtracting the estimated bias from the deterministic estimate. For individual bootstrap results of current status, both uncorrected and bias corrected plots are presented.

## 8.1.Recruitment-and-Mortality Modulated Catch-at-Age with Year Constant Selectivity

### 8.1.1 Hockey Stick with Recruitment Increasing with Spawning Stock Biomass

Current relative spawning-stock biomass, current relative fishing-mortality rates and various management reference points are shown in Table 31 for the assumption that recruitment increases with female spawning stock size over the range of estimates from the VPA. The spawning-stock size was estimated to be 70% (75% after bias correction) of the stock size at $F_{30\%}$ (about 82% of MSST; 88% after bias correction; MSST taken as (1-M)*$SSB_{30\%}$). The current fishing-mortality rate was estimated to be just below (7% after bias correction) the estimated MFMT proxy ($F_{30\%}$). The empirical 80% confidence-interval range was relatively small (16%) for the spawning-stock biomass ratio to the bench mark, while that range for the fishing-mortality rate ratio was much broader (79%). Cumulative distribution plots for various reference statistics are shown in Figure 46.

The individual bootstrap estimates (not-bias corrected) of the status of gag in 1999 all indicated that spawning-stock biomass was less than the minimum spawning-stock threshold, and the majority of cases indicated that fishing exceeded the fishing-mortality limit for the associated stock size (Figure 47). The relationship between the deterministic and median bootstrapped estimates of the current status indicated that bias was small relative to the dispersion in the estimates, and, therefore, bias correction shifted the distribution very little, but resulted in a small fraction of the outcomes indicating fishing mortality rate less than MFMT and spawning stock biomass greater than MSST. The deterministic estimate was positively biased for F and negatively biased for SSB based on bootstrap results; bias corrected plots of individual bootstrap results showed an increased proportion of current fishing levels below the fishing-mortality rate limit (Figure 47). Similar plots for $F_{max}$ reference points, showed fishing-mortality rates roughly 1.5-10 times, and spawning stock sizes roughly 20-50%, of those that would optimize yield per recruit for the whole population (Figures 48); as with the $F_{30\%}$ bootstraps, the bias was small relative to the dispersion in the estimates.

The projected recruitment under an assumption of no fishing mortality in 2002 and beyond showed relatively high levels of recruitment at about the year-2000 level for 2001 and later (Figure 49). When reference fishing-mortality rates ($F_{30\%}$, $F_{40\%}$, $F_{max}$ , and $F_{status\ quo}$) were imposed in 2002-2012, possible annual yields of 8-10 million pounds by 2012 were projected (Figure 50). Historic (1986-1999) fishing-mortality rates exceeded the benchmark rates under the projected selectivity pattern (Figure 51). The projected median fishing-mortality rates relative to $F_{30\%}$ and $F_{max}$, associated with yields from 2 - 8 million pounds, indicated that constant removals of 6 million and 5 million pounds, respectively, would result in projected fishing-mortality rates equal to, or below, the reference level before 2012 (Figures 51 and 52). Projected female spawning-stock sizes relative to reference spawning-stock sizes indicated that the $F_{30\%}$ and $F_{40\%}$ levels of spawning stock biomass might be reached before 2012 with yields of 6 million pounds, while the spawning-stock size associated with $F_{max}$ would be achieved with yields of 4 million pounds under the projected selectivity pattern (Figures 53, 54 and 55). Male spawning-stock biomass was estimated to have been well below 1% of unexploited levels during the 1980's and most of the 1990's, and was projected to increase under all constant fishing-mortality rate scenarios, and under the yield scenarios of 6 million pounds and less (Figure 56 and 57).

### 8.1.2 Hockey Stick with Average Recruitment above Minimum Spawning-Stock Biomass

The reference fishing-mortality rates and spawning stock sizes estimated under the average recruitment assumption were lower than under the assumption of increasing recruitment with spawning stock size while the reference spawning stock sizes were substantially lower (compare Tables 31 and 32). The relative current fishing-mortality rates and the spawning-stock biomass estimates for the most recent period were both estimated to be in excess of the reference levels for this model and stock-recruitment relationship. Cumulative distribution plots for various reference statistics are shown in Figure 58. The scatter plots of bootstrapped current status (Figures 59-60) reflected those patterns; for the

$F_{30\%}$, reference points, nearly all estimated fishing-mortality rates exceeded $F_{30\%}$, while the spawning-biomass levels ranged from about equal to about three times the spawning stock produced by fishing at $F_{30\%}$. For the $F_{max}$ reference points, most fishing-mortality rates were 2-6 times higher than the levels that would produce the maximum yield per recruit and, most spawning-stock biomass estimates were less that the spawning-stock biomass at which yield per recruit would be maximized. The relationship between the deterministic and median reference points indicated that the estimated bias was substantially lower than the overall uncertainty in the estimates.

Median projected recruitment (Figure 61) was at a much lower level than under the assumption that recruitment would increase with spawning stock size (Figure 49), and was unaffected by the projected catch and mortality-rate levels. Projected yields at reference fishing-mortality rates ($F_{30\%}$, $F_{40\%}$, and $F_{max}$) decreased to about 1.9 million pounds in about 5 years, and then climbed to levels similar to those observed in the early 1990s ( roughly 2.5 million pounds) by 2012 (Figure 62). With yields of 4 million pounds or more, projected median spawning stock size relative to spawning stock size at $F_{30\%}$ declined to very low levels in less than a decade (Figure 65).

8.2. Age-Length-Key and Stochastic growth-curve-based Catch-at-Age with Year Variable Selectivity

8.2.1 Hockey Stick with Recruitment Increasing with Spawning Stock Biomass

For the ALK+ catch-at-age combined with the assumptions of 1) year constant index selectivity, 2) increasing recruitment with spawning-stock size to the maximum 1986-1999 estimated spawning-stock size, and 3) the projected selectivity pattern, the estimated current stock size (without bias correction) was about 86% of the estimated spawning-stock size associated with $F_{30\%}$ and slightly above the minimum stock size threshold (Table 33). The 1997-1999 geometric mean fishing mortality was estimated to be below $F_{30\%}$ – approximately 23% for the uncorrected estimate, and just below for the bias-corrected estimate. Cumulative-distribution plots for various reference statistics are shown in Figure 70. Scatter plots of the current status relative to bench marks indicated that most of the spawning-stock size estimates were between 0.6 and 1.1 times the spawning-stock size associated with $F_{30\%}$, and the estimated fishing-mortality rates ranged from about 0.2 to 1.1 times $F_{30\%}$ (Figure 71). There appeared to be little or no bias in the spawning-stock biomass ratios, but the deterministic estimate of the fishing-mortality rate ratio was about 33% higher than the median ratio from the bootstraps. The uncorrected and bias corrected scatter plots of the ratios with respect to $F_{max}$ indicated that nearly all estimated stock sizes were below the stock size that would produce the maximum yield per recruit (Figure 72). Roughly half of the estimated fishing-mortality rates were below $F_{max}$ in the uncorrected case, while nearly all were above $F_{max}$ after bootstrap bias correction.

The projected recruitments under all scenarios investigated increased to levels somewhat higher than highest level estimated for 1986-1996, and were highly variable with upper 80% empirical confidence limits over 35 million recruits (Figure 73). The median of projected yields under all fishing-mortality rate scenarios increased to levels considerably higher than those estimated for 1986-1999 (Figure 74). The median female spawning-stock sizes were estimated to have been less than 50% of reference levels through the mid 1990's (Figures 77-80). Historic median male spawning-stock biomass was estimated to have been less than 1% of equilibrium levels under no fishing (Figure 80).

8.2.2 Hockey Stick with Average Recruitment above Minimum Spawning-stock Biomass

Under the assumption that recruitment would equal the 1986-1996 average at spawning-stock sizes equal to or greater than the minimum observed during 1986-1999, the projected fishing-mortality rates were similar to those projected under the assumption that recruitment would increase with spawning-stock size (Table 34). In this case, the spawning-stock size in 2000 from the VPA was estimated to be well above the stock size associated with $F_{30\%}$, but the bootstrap bias corrected spawning-stock size was estimated to be at 68% of that level. Cumulative-distribution plots for various reference statistics are shown in Figure 82. The scatter plot of bootstrapped solutions to the VPA with statistics relative to the $F_{30\%}$ reference points showed the wide spread in solutions, with respect to the spawning-stock status in 2000, and the relatively large differences in the deterministic VPA estimates and the bootstrapped medians (Figure 83). The wide scatter and relatively large estimated bias in spawning-stock biomass both suggest a great deal of uncertainty in the estimates of stock status, and the associated management reference points.

The median of projected recruitment was at levels similar to those estimated for late 1980's and early 1990's, and substantially below recent levels of recruitment (Figure 85). Estimated median yield at reference fishing-mortality rates was projected to stabilize near historically high levels (Figure 86). Yields of about 6 million pounds resulted in projected median spawning-stock sizes above the stock size associated with $F_{30\%}$ in 2005-2012, although there was considerable uncertainty in the projected outcomes (Figure 89). Historic median mature male biomass was estimated to be about 1% of that which might occur under unfished conditions and to be at 4-5% of such levels by 2012 if fishing were to occur at $F_{30\%}$ (Figure 92).

8.3. Age-Length-Key and Stochastic growth-curve-based Catch-at-Age with Year Constant Selectivity

This case, which is presented as a sensitivity treatment, was derived from the VPA in which fishing-mortality rates of ages 7-10+ were forced to be equal to the fishing-mortality rate on age 6 fish, to investigate alternatives to the dome shaped index selectivity patterns.

8.3.1 Hockey Stick with Recruitment Increasing with Spawning-stock Biomass

For the ALK+ catch-at-age combined with the assumptions of 1) year constant index selectivity, 2) increasing recruitment with spawning-stock size to the maximum 1986-1999 estimated spawning-stock size, and 3) the projected selectivity pattern, the estimated current stock size was about 8% below the spawning-stock size associated with $SPR_{30\%}$ without bias correction, and 2% below after bias correction (Table 35). Estimated fishing-mortality rates were 65-70% below $F_{30\%}$. Cumulative-distribution plots for various reference statistics are shown in Figure 94. The scatter plots of bootstrap estimates of the relative status measures indicated that the majority of solutions were below $F_{30\%}$, and that the majority of the estimated spawning-stock sizes were above the minimum stock-size threshold (Figures 95 and 96).

The median of projected recruitment was slightly higher that the estimated recruitments in 1993 and 1994 (Figure 97). Projected long term yields associated with the various reference fishing-mortality rates were on the order of 14 million pounds, more than twice the maximum historic (1986-1999) levels (Figure 98). Historic fishing-mortality rates were estimated to be between 0.5 and 1.5 times $F_{30\%}$., while projected fishing-mortality rates at yields of 8 million pounds and less were projected to decline to below one-half of $F_{30\%}$.(Figure 99). Historic levels of spawning-stock biomass were estimated to have been roughly 25% of the spawning-stock biomass associated with $F_{30\%}$, and spawning-stock biomass was projected to reach levels more than 1.75 times the spawning-stock biomass associated with $F_{30\%}$ at yields of 8 million pounds (Figure 101). Male spawning-stock biomass was estimated to have been below 1% of unfished levels in 1986 through 1999, and then was projected to increase (Figures 104 and 105).

8.3.2 Hockey Stick with Average Recruitment above Minimum Spawning-stock Biomass

For the ALK+ catch-at-age combined with the assumptions of 1) year constant index selectivity, 2) average recruitment above the minimum spawning-stock size estimated for 1986-1999, and 3) the projected selectivity pattern, the current stock size was estimated to be roughly 40% to 60% above the spawning-stock size at $F_{30\%}$, and, as with the increasing recruitment bootstrapped VPAs, the 1996-1999 geometric mean fishing-mortality rate was estimated to be roughly 30% below $F_{30\%}$ (Table 36). Cumulative-distribution plots for various reference statistics are shown in Figure 106. The scatter plots of bootstrapped estimates of current status indicated a broad range of solutions with respect to relative spawning-stock size with most ranging from 0.85 (the minimum stock size threshold) to 3 times the stock size at $F_{30\%}$ under equilibrium conditions; with most estimates of fishing-mortality rates less than $F_{30\%}$ (Figure 107).

Median recruitment was projected to be at about the 1991 level; the higher levels of recruitment estimated for the mid- and late-1990s were close to, or above, the upper 80% empirical confidence level for the projected recruitments (Figure 109); projected recruitments were unaffected by fishing at reference fishing-mortality rates, or by levels of landings up to 8 million pounds. Projected yields by 2012 under reference fishing-mortality rates were at about 5.5 million pounds, which was about as high as, or higher than, all but two of the landings levels during 1986-1999 (Figure 110). If fishing mortality in 2000 and 2001 were at the projected levels, about 60% of $F_{30\%}$, then the projections indicated that yields of 6 million pounds would not result in $F_{30\%}$ by 2012 (Figure 111). Median historic male spawning-stock biomass was estimated to have been at about 1% to1.5% of levels under equilibrium unfished conditions; the projections indicated that male spawning-stock biomass would increase until about 2005, to at least 5% of the unfished condition (Figures 116 and 117) .

8.4 Overview of Management Reference Point and Projection Results

The two stock-recruitment assumptions investigated had different implications for management with respect to spawning-stock status. The average recruitment assumption implied that the recruitment levels estimated for the mid- to late-1990s were unusual, and that recent harvest rates could not be sustained. It also implied that the minimum stock-size threshold is relatively low. The assumption that recruitment increases with spawning-stock size resulted in higher estimates of both long term yield and the minimum stock size threshold. Under that stock-recruitment assumcption, recent (1986-1999) estimated spawning-stock sizes would be below the minimum stock size threshold.

In contrast to the spawning-stock status results, the relative fishing-mortality rate measures were only slightly influenced by the assumed relationship between stock and recruitment.

An important point for the RFSAP to consider is the choice of MSY proxies given the protogynous hermaphroditic life history of gag grouper. As can be seen in Tables 31-36, $F_{max}$ is typically about half of $F_{30\%}$ while the female SSB at $F_{max}$ is about double the SSB at $F_{30\%}$. This happens because reproductive potential for the average female decreases rapidly after age 9 (Figure 41), whereas the average weight per fish increases substantially. Accordingly, increasing F has a proportionally greater negative impact on the biomass of older fish. Under the projected selectivity scenario's examined here, an $F_{max}$ policy would achieve greater long-term yields and a higher SPR (43% - 65%) than would policies based on $F_{30\%}$ or $F_{40\%}$. An $F_{max}$ policy also leads to less-optimistic appraisals of stock status-- in every case the stock is perceived as both overfished and undergoing overfishing (Figures 118 and 119).

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Table 1. Proportion of gag + black grouper in commercial landings assumed to be gag by state and for Florida by county as reported by Schirippa and Goodyear (1994).

| state | county | proportion gag |
|---|---|---|
| TX | all | 1.000 |
| LA | all | 1.000 |
| MI | all | 1.000 |
| AL | all | 1.000 |
| wFL | Escambia | 1.000 |
| wFL | Santa Rosa | 1.000 |
| wFL | Okaloosa | 1.000 |
| wFL | Walton | 1.000 |
| wFL | Bay | 1.000 |
| wFL | Gulf | 1.000 |
| wFL | Franklin | 1.000 |
| wFL | Wakulla/Jefferson | 1.000 |
| wFL | Taylor | 1.000 |
| wFL | Dixie | 1.000 |
| wFL | Levy | 1.000 |
| wFL | Citrus | 1.000 |
| wFL | Hernando | 1.000 |
| wFL | Pasco | 1.000 |
| wFL | Pinellas | 1.000 |
| wFL | Hillsborough | 1.000 |
| wFL | Manatee | 0.704 |
| wFL | Sarasota | 0.653 |
| wFL | Charlotte | 0.633 |
| wFL | Lee | 0.438 |
| wFL | Collier | 0.320 |
| wFL | Monroe | 0.298 |

Table 2. Annual proportion of unclassified groupers reported from Florida assumed to be gag as estimated from the proportion of calculated gag in the commercial landings of identified groupers in the accumulated landings data.

| year | proportion gag |
|---|---|
| 1986 | 0.1626 |
| 1987 | 0.1460 |
| 1988 | 0.1493 |
| 1989 | 0.1623 |
| 1990 | 0.2280 |
| 1991 | 0.1920 |
| 1992 | 0.2227 |
| 1993 | 0.1910 |
| 1994 | 0.1990 |
| 1995 | 0.2124 |
| 1996 | 0.2166 |
| 1997 | 0.1971 |
| 1998 | 0.3236 |
| 1999 | 0.2131 |
| 2000 | 0.2287 |

Table 3. Calculated commercial landings of gag from the U.S. waters in the Gulf of Mexico by year and state in thousands of pounds gutted weight. Landings for 2000 are preliminary.

| | TX | LA | MI | AL | WFL | total |
|---|---|---|---|---|---|---|
| 1986 | 8 | 34 | | | 1,537 | 1,578 |
| 1987 | 2 | 37 | | 2 | 1,399 | 1,439 |
| 1988 | 2 | 30 | | 16 | 1,091 | 1,139 |
| 1989 | 2 | 16 | | 0 | 1,602 | 1,620 |
| 1990 | 0 | 19 | | 1 | 1,748 | 1,768 |
| 1991 | 1 | 25 | | | 1,481 | 1,507 |
| 1992 | | 16 | | | 1,555 | 1,571 |
| 1993 | 2 | 19 | 1 | | 1,747 | 1,769 |
| 1994 | 1 | 16 | 1 | | 1,519 | 1,537 |
| 1995 | 2 | 22 | 0 | | 1,515 | 1,538 |
| 1996 | 0 | 22 | 1 | | 1,446 | 1,469 |
| 1997 | 2 | 30 | 2 | | 1,466 | 1,499 |
| 1998 | 1 | 50 | 6 | 1 | 2,347 | 2,405 |
| 1999 | 4 | 47 | 4 | | 1,920 | 1,975 |
| 2000 | 3 | 45 | 6 | 1 | 1,620 | 1,675 |

Table 4. Calculated commercial landings (thousands of pounds) of gag from U.S. Gulf of Mexico waters by year and gear in thousands of pounds gutted weight.

| | fish traps | handline | longline | other | spear | total |
|---|---|---|---|---|---|---|
| 1986 | 13 | 1,084 | 476 | 6 | 0 | 1,578 |
| 1987 | 15 | 792 | 627 | 3 | 2 | 1,439 |
| 1988 | 9 | 699 | 404 | 24 | 4 | 1,139 |
| 1989 | 10 | 1,146 | 424 | 37 | 3 | 1,620 |
| 1990 | 24 | 1,075 | 627 | 40 | 1 | 1,768 |
| 1991 | 37 | 925 | 503 | 41 | 1 | 1,507 |
| 1992 | 28 | 921 | 578 | 43 | 1 | 1,571 |
| 1993 | 54 | 1,118 | 549 | 49 | | 1,769 |
| 1994 | 26 | 1,090 | 376 | 45 | | 1,537 |
| 1995 | 69 | 1,117 | 298 | 54 | 0 | 1,538 |
| 1996 | 31 | 1,077 | 297 | 57 | 7 | 1,469 |
| 1997 | 31 | 1,080 | 320 | 68 | 2 | 1,499 |
| 1998 | 19 | 1,780 | 507 | 99 | 0 | 2,405 |
| 1999 | 21 | 1,277 | 555 | 122 | 1 | 1,975 |
| 2000 | 21 | 1,003 | 391 | 241 | 19 | 1,675 |

Table 5. Comparison of calculated commercial landings (thousands of pounds) for the U.S. Gulf of Mexico waters in gutted weight from Schirippa and Legault (1997) and this assessment.

| | Schirippa and Legualt (1997) | this assessment | difference |
|---|---|---|---|
| 1986 | 1590 | 1565 | 25 |
| 1987 | 1478 | 1427 | 51 |
| 1988 | 1171 | 1122 | 50 |
| 1989 | 1703 | 1612 | 92 |
| 1990 | 1812 | 1763 | 49 |
| 1991 | 1522 | 1503 | 19 |
| 1992 | 1575 | 1569 | 6 |
| 1993 | 1776 | 1766 | 10 |
| 1994 | 1547 | 1536 | 11 |
| 1995 | 1561 | 1536 | 25 |
| 1996 | 1478 | 1467 | 11 |

Table 6. Total estimated recreational landings (and dead discards from MRFSS) of reported gag (not including any black grouper) by state and year in number of fish.

| | state | | | | | |
|---|---|---|---|---|---|---|
| year | TX | LA | MI | AL | wFL | total |
| 1986 | 511 | 970 | 1741 | 9306 | 172926 | 185454 |
| 1987 | 761 | 361 | 2375 | 3312 | 199125 | 205934 |
| 1988 | 238 | 335 | 0 | 941 | 204249 | 205763 |
| 1989 | 199 | 4171 | 570 | 1340 | 171837 | 178117 |
| 1990 | 358 | 43 | 62 | 951 | 189054 | 190468 |
| 1991 | 480 | 1106 | 0 | 1978 | 272187 | 275751 |
| 1992 | 150 | 2014 | 613 | 1704 | 269179 | 273660 |
| 1993 | 358 | 1874 | 2116 | 3304 | 367740 | 375392 |
| 1994 | 238 | 2938 | 1278 | 6874 | 289645 | 300973 |
| 1995 | 183 | 1132 | 38 | 8479 | 406699 | 416531 |
| 1996 | 276 | 11344 | 6011 | 19049 | 331057 | 367737 |
| 1997 | 142 | 932 | 577 | 10603 | 418837 | 431091 |
| 1998 | 1144 | 3644 | 3814 | 11123 | 564947 | 584672 |
| 1999 | 280 | 17529 | 549 | 31323 | 533382 | 583063 |
| 2000 | | 2888 | 2304 | 25523 | 585135 | 615850 |

Table 7. Total estimated landings (and dead discards from MRFSS) of calculated gag (including some black grouper) by state and year from recreational fisheries in number of fish.

| | state | | | | | |
|---|---|---|---|---|---|---|
| year | TX | LA | MI | AL | wFL | total |
| 1986 | 652 | 2,450 | 1,741 | 19,949 | 666,131 | 690,923 |
| 1987 | 808 | 4,425 | 2,375 | 5,927 | 462,858 | 476,393 |
| 1988 | 263 | 6,379 | 144 | 953 | 571,546 | 579,285 |
| 1989 | 219 | 4,174 | 1,174 | 1,391 | 384,458 | 391,416 |
| 1990 | 430 | 43 | 62 | 987 | 192,968 | 194,490 |
| 1991 | 487 | 1,110 | 0 | 2,004 | 262,074 | 265,675 |
| 1992 | 159 | 2,023 | 613 | 1,713 | 260,743 | 265,251 |
| 1993 | 364 | 1,880 | 2,116 | 3,344 | 343,255 | 350,959 |
| 1994 | 245 | 2,939 | 1,278 | 6,883 | 270,993 | 282,338 |
| 1995 | 186 | 1,136 | 38 | 8,481 | 373,692 | 383,533 |
| 1996 | 285 | 11,344 | 6,011 | 19,098 | 307,935 | 344,673 |
| 1997 | 149 | 940 | 577 | 10,605 | 396,525 | 408,796 |
| 1998 | 1,153 | 4,865 | 3,814 | 11,144 | 511,019 | 531,995 |
| 1999 | 285 | 18,018 | 549 | 31,375 | 473,880 | 524,107 |
| 2000 | | 2,888 | 2,304 | 25,523 | 513,473 | 544,188 |

Table 8. Estimated total landed yield of Gulf of Mexico calculated gag (including some black and unclassified groupers) by year and mode from recreational fisheries in thousands of pounds gutted weight.

| | charter | headboat | private | shore | total |
|---|---|---|---|---|---|
| 1986 | 1,199 | 267 | 2,344 | 238 | 4,048 |
| 1987 | 802 | 167 | 1,496 | 13 | 2,479 |
| 1988 | 557 | 138 | 2,536 | 98 | 3,329 |
| 1989 | 367 | 276 | 2,067 | 70 | 2,781 |
| 1990 | 258 | 159 | 1,004 | 0 | 1,421 |
| 1991 | 126 | 94 | 1,755 | 130 | 2,104 |
| 1992 | 489 | 103 | 1,129 | 61 | 1,782 |
| 1993 | 649 | 132 | 1,288 | 67 | 2,136 |
| 1994 | 420 | 135 | 1,099 | 36 | 1,691 |
| 1995 | 512 | 100 | 1,456 | 82 | 2,151 |
| 1996 | 478 | 86 | 1,082 | 31 | 1,677 |
| 1997 | 851 | 82 | 1,586 | 24 | 2,544 |
| 1998 | 1,337 | 201 | 1,525 | 157 | 3,220 |
| 1999 | 899 | 158 | 1,943 | 41 | 3,041 |

Table 9. Estimated landings from recreational fisheries in the Gulf of Mexico of calculated gag (including some black grouper) by survey and year in number of fish.

| | Texas P&W | Headboat | MRFSS (A+B1) | Grand Total |
|---|---|---|---|---|
| 1986 | 102 | 44,927 | 645,894 | 690,923 |
| 1987 | 212 | 34,512 | 441,669 | 476,393 |
| 1988 | | 26,521 | 552,764 | 579,285 |
| 1989 | 24 | 35,231 | 356,161 | 391,416 |
| 1990 | 269 | 19,195 | 175,026 | 194,490 |
| 1991 | 329 | 11,491 | 253,855 | 265,675 |
| 1992 | | 13,838 | 251,413 | 265,251 |
| 1993 | 29 | 19,511 | 331,419 | 350,959 |
| 1994 | 71 | 20,637 | 261,630 | 282,338 |
| 1995 | | 17,849 | 365,684 | 383,533 |
| 1996 | 121 | 16,144 | 328,408 | 344,673 |
| 1997 | | 15,654 | 393,142 | 408,796 |
| 1998 | 44 | 36,419 | 495,532 | 531,995 |
| 1999 | 45 | 32,786 | 491,276 | 524,107 |
| 2000 | | | 544,188 | 544,188 |

Table 10. Estimated MRFSS landings plus dead discards (A+B1) in number of fish from Gulf of Mexico recreational fisheries for calculated gag (including some black grouper) and associated coefficients of variation by year and wave.

| wave: | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | catch | cv | catch | cv | catch | cv | catch | cv | catch | cv | catch | cv |
| 1986 | 34,394 | 0.292 | 126,293 | 0.171 | 206,966 | 0.171 | 81,186 | 0.190 | 143,515 | 0.247 | 53,535 | 0.294 |
| 1987 | 35,094 | 0.340 | 121,981 | 0.220 | 68,497 | 0.220 | 69,000 | 0.213 | 110,756 | 0.271 | 36,341 | 0.272 |
| 1988 | 23,498 | 0.393 | 46,669 | 0.258 | 149,682 | 0.258 | 192,728 | 0.166 | 64,190 | 0.232 | 75,998 | 0.272 |
| 1989 | 105,848 | 0.192 | 61,109 | 0.275 | 128,926 | 0.275 | 9,308 | 0.359 | 34,590 | 0.323 | 16,379 | 0.523 |
| 1990 | 8,916 | 0.478 | 22,421 | 0.613 | 20,787 | 0.613 | 12,830 | 0.433 | 20,270 | 0.394 | 89,803 | 0.356 |
| 1991 | 51,184 | 0.330 | 31,924 | 0.303 | 24,553 | 0.303 | 59,553 | 0.369 | 40,533 | 0.230 | 46,107 | 0.356 |
| 1992 | 11,689 | 0.290 | 30,958 | 0.197 | 42,640 | 0.197 | 37,865 | 0.272 | 70,084 | 0.155 | 58,176 | 0.161 |
| 1993 | 54,251 | 0.183 | 48,901 | 0.238 | 78,063 | 0.238 | 39,130 | 0.164 | 42,800 | 0.237 | 68,274 | 0.172 |
| 1994 | 7,652 | 0.432 | 45,103 | 0.185 | 51,420 | 0.185 | 78,682 | 0.136 | 11,231 | 0.276 | 67,542 | 0.175 |
| 1995 | 56,780 | 0.246 | 89,717 | 0.233 | 69,379 | 0.233 | 41,037 | 0.250 | 45,644 | 0.269 | 63,126 | 0.201 |
| 1996 | 16,908 | 0.365 | 39,620 | 0.235 | 75,530 | 0.235 | 80,467 | 0.189 | 67,655 | 0.231 | 48,226 | 0.270 |
| 1997 | 69,711 | 0.249 | 38,919 | 0.226 | 77,589 | 0.226 | 56,846 | 0.237 | 43,345 | 0.234 | 106,729 | 0.171 |
| 1998 | 90,407 | 0.204 | 54,599 | 0.178 | 80,068 | 0.178 | 66,357 | 0.137 | 104,434 | 0.163 | 99,661 | 0.275 |
| 1999 | 75,065 | 0.166 | 101,206 | 0.129 | 104,583 | 0.129 | 57,252 | 0.137 | 49,844 | 0.183 | 103,323 | 0.159 |
| 2000 | 81,050 | 0.211 | 90,993 | 0.200 | 126,110 | 0.200 | 48,271 | 0.210 | 91,209 | 0.209 | 106,552 | 0.181 |

Table 11. Estimated MRFSS number of live discards (B2) of calculated gag (including some black grouper) and associated coefficients of variation by year and wave.

| | wave | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| year | catch | cv | catch | cv | catch | cv | catch | cv | catch | cv | catch | cv |
| 1986 | 15,313 | 0.505 | 4,878 | 0.477 | 3,557 | 0.622 | 13,506 | 0.536 | 14,204 | 0.541 | 3,247 | 0.604 |
| 1987 | 1,949 | 1.000 | 23,760 | 0.414 | 20,280 | 0.511 | 0 | 0.000 | 19,213 | 0.465 | 58,886 | 0.484 |
| 1988 | 2,390 | 0.824 | 22,325 | 0.494 | 27,544 | 0.601 | 8,268 | 0.496 | 10,710 | 0.453 | 21,733 | 0.428 |
| 1989 | 57,295 | 0.323 | 48,339 | 0.537 | 32,761 | 0.365 | 51,562 | 0.424 | 33,361 | 0.278 | 66,203 | 0.498 |
| 1990 | 66,348 | 0.421 | 91,250 | 0.737 | 3,842 | 0.745 | 26,995 | 0.324 | 39,487 | 0.423 | 186,208 | 0.280 |
| 1991 | 121,240 | 0.341 | 52,186 | 0.386 | 135,419 | 0.376 | 52,858 | 0.539 | 268,795 | 0.307 | 244,562 | 0.226 |
| 1992 | 20,305 | 0.324 | 124,397 | 0.178 | 145,938 | 0.187 | 52,936 | 0.339 | 176,637 | 0.221 | 233,855 | 0.206 |
| 1993 | 216,277 | 0.207 | 66,736 | 0.249 | 158,177 | 0.200 | 202,376 | 0.165 | 183,875 | 0.205 | 468,609 | 0.128 |
| 1994 | 58,727 | 0.245 | 328,778 | 0.149 | 340,356 | 0.122 | 348,826 | 0.118 | 213,606 | 0.129 | 524,797 | 0.119 |
| 1995 | 349,869 | 0.144 | 302,932 | 0.137 | 382,346 | 0.151 | 244,559 | 0.142 | 265,092 | 0.163 | 480,653 | 0.133 |
| 1996 | 123,582 | 0.178 | 108,400 | 0.153 | 277,289 | 0.129 | 202,517 | 0.141 | 253,648 | 0.140 | 233,001 | 0.123 |
| 1997 | 183,597 | 0.146 | 156,303 | 0.170 | 442,287 | 0.159 | 273,349 | 0.142 | 225,660 | 0.121 | 447,388 | 0.138 |
| 1998 | 286,395 | 0.166 | 264,264 | 0.146 | 402,890 | 0.115 | 536,272 | 0.141 | 283,010 | 0.132 | 337,529 | 0.103 |
| 1999 | 300,331 | 0.105 | 317,132 | 0.083 | 318,519 | 0.121 | 191,218 | 0.104 | 182,531 | 0.148 | 234,581 | 0.115 |
| 2000 | 234,579 | 0.139 | 131,186 | 0.142 | 270,125 | 0.132 | 213,663 | 0.127 | 240,247 | 0.135 | 216,224 | 0.128 |

Table 12. Total catch (landings and discards) of gag in the Gulf of Mexico by sector for 1986-1999 in thousands of fish.

| | commercial | | recreational | | total | | |
|---|---|---|---|---|---|---|---|
| | landings | discards | landings | landings | landings | discards | all |
| 1986 | 132.6 | 0.0 | 690.9 | 151.3 | 823.5 | 151.3 | 974.8 |
| 1987 | 97.6 | 0.0 | 476.4 | 111.0 | 574.0 | 111.0 | 685.0 |
| 1988 | 68.1 | 0.0 | 579.3 | 98.0 | 647.4 | 98.0 | 745.4 |
| 1989 | 100.2 | 0.0 | 391.4 | 173.0 | 491.6 | 173.0 | 664.6 |
| 1990 | 101.1 | 1.1 | 194.5 | 153.7 | 295.6 | 154.9 | 450.4 |
| 1991 | 96.3 | 1.1 | 265.7 | 328.4 | 362.0 | 329.4 | 691.4 |
| 1992 | 97.8 | 1.0 | 265.3 | 292.0 | 363.0 | 293.0 | 656.0 |
| 1993 | 122.0 | 1.2 | 351.0 | 467.3 | 472.9 | 468.5 | 941.5 |
| 1994 | 120.4 | 5.7 | 282.3 | 651.8 | 402.7 | 657.5 | 1,060.3 |
| 1995 | 122.3 | 12.4 | 383.5 | 715.7 | 505.8 | 728.0 | 1,233.9 |
| 1996 | 152.3 | 0.2 | 344.7 | 448.3 | 497.0 | 448.5 | 945.6 |
| 1997 | 158.4 | 0.5 | 408.8 | 625.3 | 567.2 | 625.8 | 1,193.0 |
| 1998 | 239.5 | 1.3 | 532.0 | 749.3 | 771.5 | 750.5 | 1,522.1 |
| 1999 | 165.5 | 1.3 | 524.1 | 556.1 | 689.6 | 557.4 | 1,247.0 |

Table 13. Total yield (landings and discards) of gag in the Gulf of Mexico by sector for 1986-1999 in thousands of pounds.

| | commercial | | recreational | | total | | |
|---|---|---|---|---|---|---|---|
| | landings | discards | landings | discards | landings | discards | all |
| 1986 | 1,578 | - | 4,048 | 282 | 5,626 | 282 | 5,907 |
| 1987 | 1,438 | - | 2,479 | 197 | 3,917 | 197 | 4,114 |
| 1988 | 1,139 | - | 3,329 | 182 | 4,467 | 182 | 4,649 |
| 1989 | 1,619 | - | 2,781 | 320 | 4,400 | 320 | 4,720 |
| 1990 | 1,766 | 2 | 1,421 | 280 | 3,187 | 283 | 3,470 |
| 1991 | 1,506 | 2 | 2,104 | 611 | 3,611 | 613 | 4,223 |
| 1992 | 1,571 | 2 | 1,782 | 540 | 3,353 | 542 | 3,895 |
| 1993 | 1,768 | 3 | 2,136 | 860 | 3,904 | 862 | 4,767 |
| 1994 | 1,537 | 9 | 1,691 | 1,196 | 3,228 | 1,205 | 4,433 |
| 1995 | 1,538 | 27 | 2,151 | 1,332 | 3,688 | 1,359 | 5,047 |
| 1996 | 1,469 | 0 | 1,677 | 839 | 3,146 | 839 | 3,985 |
| 1997 | 1,499 | 1 | 2,544 | 1,162 | 4,043 | 1,163 | 5,206 |
| 1998 | 2,404 | 3 | 3,220 | 1,393 | 5,623 | 1,395 | 7,019 |
| 1999 | 1,974 | 3 | 3,041 | 1,021 | 5,015 | 1,023 | 6,038 |

Table 14. Initial catch at age (iteration 1) derived with the recruitment-and-mortality modulated method (Goodyear 1997), the Cass-Calay *et al*. growth curve, an M of 0.15, fishing mortality rates from age 0 and older of 0.0, 0.05, 0.1, 0.2 and 0.3 for ages and the young of the year index from seas grass tows with an average value for years prior to 1991.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 155,283 | 243,834 | 191,580 | 142,631 | 94,399 | 56,440 | 34,078 | 20,905 | 13,045 | 8,196 | 14,378 |
| **1987** | 112,266 | 160,485 | 140,165 | 101,163 | 66,796 | 40,408 | 24,617 | 15,140 | 9,348 | 5,759 | 8,883 |
| **1988** | 135,471 | 164,556 | 151,718 | 108,428 | 68,230 | 41,035 | 25,993 | 17,013 | 11,421 | 7,714 | 13,822 |
| **1989** | 134,813 | 138,225 | 85,639 | 78,921 | 73,473 | 55,587 | 37,997 | 24,377 | 14,939 | 8,848 | 11,798 |
| **1990** | 75,693 | 99,871 | 70,016 | 52,023 | 45,007 | 35,227 | 25,675 | 17,522 | 11,401 | 7,164 | 10,819 |
| **1991** | 173,627 | 168,684 | 100,828 | 67,379 | 58,150 | 44,266 | 29,551 | 18,423 | 11,402 | 7,178 | 11,946 |
| **1992** | 139,845 | 246,297 | 76,460 | 55,816 | 42,042 | 30,761 | 22,136 | 15,147 | 9,997 | 6,465 | 11,072 |
| **1993** | 230,927 | 198,975 | 324,585 | 53,768 | 43,942 | 30,753 | 20,689 | 13,728 | 8,990 | 5,764 | 9,371 |
| **1994** | 298,629 | 376,493 | 96,103 | 214,340 | 21,437 | 15,607 | 11,690 | 8,505 | 5,985 | 4,081 | 7,388 |
| **1995** | 309,870 | 306,087 | 400,914 | 34,630 | 143,684 | 11,667 | 7,976 | 5,714 | 4,214 | 3,053 | 6,056 |
| **1996** | 196,845 | 242,898 | 62,866 | 367,032 | 10,830 | 48,930 | 4,102 | 3,297 | 2,614 | 1,981 | 4,163 |
| **1997** | 279,306 | 318,044 | 181,441 | 18,125 | 337,382 | 8,462 | 37,663 | 2,722 | 2,138 | 1,800 | 5,870 |
| **1998** | 325,898 | 405,699 | 273,808 | 146,703 | 7,070 | 309,053 | 8,036 | 36,884 | 2,570 | 1,864 | 4,474 |
| **1999** | 224,178 | 333,328 | 261,062 | 155,804 | 73,164 | 2,510 | 164,093 | 4,724 | 23,264 | 1,594 | 3,236 |

Table 15. Catch-at-age estimated from semi-annual age-length-keys and stochastic growth as estimated by Cummings and Parrack (in prep.). Note that the estimated catch at age 1 in 1999 of 0 was replaced with a 1.

| | **age 0** | **age 1** | **age 2** | **age 3** | **age 4** | **age 5** | **age 6** | **age 7** | **age 8** | **age 9** | **age 10+** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 7,231 | 64,461 | 350,531 | 177,896 | 189,066 | 62,866 | 60,744 | 11,497 | 20,485 | 6,572 | 23,421 |
| **1987** | 4,629 | 59,839 | 184,745 | 223,216 | 42,314 | 77,627 | 50,236 | 16,789 | 5,417 | 6,069 | 14,146 |
| **1988** | 18,540 | 70,832 | 191,872 | 198,666 | 117,687 | 43,311 | 41,574 | 26,223 | 7,078 | 1,910 | 27,709 |
| **1989** | 10,127 | 73,994 | 229,617 | 39,667 | 55,601 | 124,165 | 40,828 | 47,524 | 22,836 | 13,062 | 7,193 |
| **1990** | 9,380 | 32,472 | 122,281 | 88,743 | 32,786 | 56,295 | 39,734 | 37,125 | 14,955 | 5,004 | 11,628 |
| **1991** | 9,969 | 58,601 | 275,651 | 129,777 | 22,378 | 63,390 | 70,221 | 33,688 | 11,957 | 1,800 | 13,987 |
| **1992** | 32,513 | 50,295 | 210,549 | 229,639 | 27,754 | 38,242 | 29,874 | 22,935 | 1,186 | 1,710 | 11,334 |
| **1993** | 59,339 | 18,275 | 234,564 | 337,272 | 200,138 | 27,751 | 22,385 | 14,774 | 14,004 | 3,961 | 9,020 |
| **1994** | 64,289 | 32,608 | 208,020 | 293,465 | 257,854 | 152,644 | 17,866 | 9,691 | 8,648 | 6,267 | 8,898 |
| **1995** | 57,806 | 154,514 | 346,916 | 196,192 | 229,853 | 117,193 | 95,442 | 17,547 | 4,477 | 508 | 13,409 |
| **1996** | 54,530 | 32,625 | 460,958 | 253,663 | 68,591 | 30,673 | 24,639 | 6,839 | 4,705 | 2,008 | 6,319 |
| **1997** | 30,440 | 98,724 | 510,994 | 273,180 | 191,973 | 43,160 | 12,323 | 7,481 | 7,966 | 4,649 | 12,056 |
| **1998** | 36,753 | 283,133 | 252,555 | 233,295 | 363,554 | 280,989 | 31,926 | 15,772 | 10,428 | 2,301 | 11,345 |
| **1999** | 48,426 | 1 | 143,060 | 742,111 | 101,752 | 100,256 | 80,836 | 11,082 | 5,951 | 4,976 | 8,499 |

Table 16. Indices of abundance available for use in assessment.[1]

| | Seagrass Tows year interacion | | Seagrass Tows year only model | | handline | | longline | | trap (fixed effects) | | MRFSS charter + private | | head boat | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| indexing: | n fish index | cv | n fish index | cv | biomass index | cv | biomass index | cv | biomass index | cv | n fish index | cv | n fish index | cv |
| 1981 | | | | | | | | | | | 9.394 | 0.523 | | |
| 1982 | | | | | | | | | | | 5.312 | 0.512 | | |
| 1983 | | | | | | | | | | | 23.116 | 0.482 | | |
| 1984 | | | | | | | | | | | 8.168 | 0.607 | | |
| 1985 | | | | | | | | | | | 3.182 | 0.652 | | |
| 1986 | | | | | | | | | | | 5.188 | 0.409 | 1.080 | 0.285 |
| 1987 | | | | | | | | | | | 4.372 | 0.365 | 1.653 | 0.180 |
| 1988 | | | | | | | | | | | 2.267 | 0.396 | 0.931 | 0.257 |
| 1989 | | | | | | | | | | | 5.850 | 0.373 | 0.793 | 0.278 |
| 1990 | | | | | | | | | | | 12.703 | 0.374 | 0.635 | 0.265 |
| 1991 | 4.756 | 0.309 | 2.60 | 0.311 | 1587.5 | | 939.9 | 0.277 | 38.84 | 0.401 | 15.519 | 0.363 | 0.552 | 0.326 |
| 1992 | 0.500 | 0.591 | 0.27 | 0.615 | 2235.9 | | 1198.7 | 0.273 | 121.11 | 0.190 | 12.365 | 0.326 | 0.671 | 0.273 |
| 1993 | | . | 4.63 | 0.316 | 3483.7 | | 2808.4 | 0.134 | 267.17 | 0.118 | 17.682 | 0.317 | 0.789 | 0.240 |
| 1994 | 0.037 | 3.011 | 0.02 | 3.422 | 3369.5 | | 1715.4 | 0.114 | 315.56 | 0.110 | 30.272 | 0.313 | 0.804 | 0.244 |
| 1995 | 0.624 | 0.446 | 0.34 | 0.463 | 4201.6 | | 1678.2 | 0.118 | 678.19 | 0.135 | 26.310 | 0.311 | 0.826 | 0.299 |
| 1996 | 0.569 | 0.493 | 0.31 | 0.513 | 4497.3 | | 1753.7 | 0.096 | 228.70 | 0.182 | 30.313 | 0.312 | 1.174 | 0.206 |
| 1997 | 0.488 | 0.514 | 0.27 | 0.536 | 4955.1 | | 2195.1 | 0.096 | 332.01 | 0.157 | 32.746 | 0.302 | 1.341 | 0.191 |
| 1998 | 0.414 | 0.728 | 0.23 | 0.762 | 7897.4 | | 4500.5 | 0.083 | 779.62 | 0.119 | 37.899 | 0.296 | 1.440 | 0.184 |
| 1999 | 0.612 | 0.684 | 0.33 | 0.709 | 6900.8 | | 4934.3 | 0.095 | 757.67 | 0.143 | 29.007 | 0.294 | 1.313 | 0.188 |
| 2000 | | | | | | | | | | | 21.004 | 0.297 | | |

1. For the recruitment-and-mortality modulated ageing, the sea-grass tows, year only model was used, with additional values (0.11) derived from the mean of 1992, and 1995-1999 used for 1976-1986.

Table 17. Summary of VPA analyses for Gulf of Mexico gag using data from 1986-1999.

| | | | | | 1999 fishing mortality rates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ageing method | growth curve | index selectivity | indices | n iterations | age 0 | age 1 | age 2 | age 4 | age 6 | age 7 | age 8 | log likelihood | AIC2 | |
| probabilistic with rec and F | Cass-Calay | constant | all | 1 | | | 1.218 | 0.130 | 0.178 | | 0.042 | 3.61 | 17.77 | sensitivity run |
| probabilistic with rec and F | prev. assesments | constant | all | 1 | | | 0.365 | 0.152 | 0.119 | | 0.022 | 5.33 | 14.34 | sensitivity run |
| probabilistic with rec and F | Cass-Calay | constant | all | 5 | | | 1.781 | 0.183 | 0.339 | | 0.181 | 0.04 | 24.91 | |
| probabilistic with rec and F | Cass-Calay | constant | yoy+ comm | 2 | | | 0.635 | 0.058 | 0.016 | | 0.004 | 7.74 | 8.52 | sensitivity run |
| probabilistic with rec and F | Cass-Calay | constant | yoy + rec | 2 | | | 1.311 | 0.124 | 0.179 | | 0.074 | -3.03 | 27.20 | sensitivity run |
| probabilistic with rec and F | Cass-Calay | year variable | all | 5 | | | 0.609 | 0.343 | 0.016 | | 0.041 | -9.23 | 43.47 | |
| probabilistic with rec and F | Cass-Calay | year variable | yoy+ comm | 2 | | | 0.079 | 0.011 | 0.004 | | 0.002 | 8.82 | 6.36 | sensitivity run |
| probabilistic with rec and F | Cass-Calay | year variable | yoy + rec | 2 | | | 0.360 | 0.129 | 0.100 | | 0.016 | -9.17 | 39.49 | sensitivity run |
| ALK plus stochastic | | constant | all | | 0.018 | 0.000 | 0.096 | 0.239 | 0.118 | | 0.012 | -8.88 | 49.18 | |
| ALK plus stochastic | | constant | all | | 0.028 | 0.000 | 0.176 | 0.744 | 0.116 | | | -10.67 | 54.99 | sensitivity run |
| ALK plus stochastic | | constant | yoy+ comm | | 0.022 | 0.000 | 0.146 | 0.657 | 0.203 | | 0.010 | -10.01 | 53.76 | sensitivity run |
| ALK plus stochastic | | constant | yoy + rec | | 0.018 | 0.000 | 0.098 | 0.234 | 0.152 | | 0.012 | -12.41 | 53.28 | sensitivity run |
| ALK plus stochastic | | year variable | all | | 0.031 | 0.000 | 0.237 | 0.509 | 0.376 | | 0.081 | -14.01 | 59.45 | |
| ALK plus stochastic | | year variable | yoy+ comm | | 0.037 | 0.000 | 0.325 | 1.332 | 0.729 | | 0.182 | -11.66 | 57.06 | sensitivity run |
| ALK plus stochastic | | year variable | yoy + rec | | 0.015 | 0.000 | 0.087 | 0.159 | 0.106 | | 0.007 | -12.86 | 54.18 | sensitivity run |

Table 18. Catch at age derived with the recruitment-and-mortality modulated growth method (Goodyear 1997) run for one iteration using the growth equation used in the 1994 and 1997 assessments, M of 0.15, fishing mortality rates from age 0 and older of 0.0, 0.05, 0.1, 0.2 and 0.3 for ages and the young of the year index from seas grass tows with an average value for years prior to 1991.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 21613 | 150249 | 253456 | 197546 | 138641 | 84539 | 50674 | 30330 | 18328 | 11188 | 18204 |
| **1987** | 22261 | 102875 | 168111 | 143642 | 97253 | 59969 | 36267 | 21902 | 13239 | 7965 | 11544 |
| **1988** | 40652 | 113575 | 172609 | 154379 | 101903 | 59509 | 36576 | 23341 | 15261 | 10116 | 17479 |
| **1989** | 30932 | 118230 | 137990 | 88232 | 82243 | 70743 | 52233 | 34514 | 21277 | 12493 | 15729 |
| **1990** | 24396 | 61462 | 101548 | 70098 | 52235 | 43215 | 33692 | 23934 | 15771 | 9874 | 14192 |
| **1991** | 40441 | 139703 | 175901 | 100826 | 68161 | 56435 | 41816 | 26761 | 16182 | 9827 | 15382 |
| **1992** | 39117 | 133381 | 166095 | 119159 | 68903 | 42275 | 29805 | 20744 | 13684 | 8736 | 14141 |
| **1993** | 72411 | 182263 | 330417 | 116475 | 93844 | 58568 | 34098 | 20546 | 12776 | 7963 | 12126 |
| **1994** | 75747 | 271777 | 270329 | 305570 | 43892 | 32276 | 21960 | 14146 | 9081 | 5826 | 9651 |
| **1995** | 90308 | 249289 | 487066 | 108706 | 230729 | 21997 | 15611 | 10448 | 6923 | 4619 | 8170 |
| **1996** | 88911 | 167446 | 186044 | 386609 | 19070 | 72452 | 6408 | 5329 | 4228 | 3120 | 5940 |
| **1997** | 74652 | 236905 | 301307 | 71279 | 424482 | 12251 | 54601 | 4094 | 3153 | 2562 | 7668 |
| **1998** | 91771 | 278553 | 411036 | 231615 | 17734 | 418805 | 10761 | 49133 | 3532 | 2651 | 6468 |
| **1999** | 49630 | 197489 | 345399 | 260952 | 120634 | 4430 | 225651 | 6162 | 29899 | 2116 | 4596 |

Table 19. Catch at age derived with the recruitment-and-mortality modulated growth method (Goodyear 1997) iterated 5 times, the Cass-Calay *et al.* growth equation, M of 0.15, the young of the year index from sea grass tows with an average for years before 1991., and year constant selectivity in the VPA

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 166460 | 261922 | 193787 | 136815 | 85922 | 52077 | 31989 | 19885 | 11292 | 6582 | 8039 |
| **1987** | 119394 | 174302 | 141944 | 96543 | 61018 | 37382 | 23142 | 14330 | 7969 | 4543 | 4463 |
| **1988** | 142081 | 177841 | 156537 | 101084 | 62978 | 38166 | 24398 | 16658 | 11288 | 6366 | 8005 |
| **1989** | 144241 | 139407 | 86032 | 79846 | 73010 | 57354 | 37356 | 21864 | 12770 | 7085 | 5651 |
| **1990** | 81520 | 105176 | 63132 | 56043 | 46344 | 35074 | 25774 | 15366 | 9634 | 6234 | 6120 |
| **1991** | 185598 | 177902 | 89371 | 56732 | 67932 | 48211 | 27989 | 16517 | 8496 | 5268 | 7419 |
| **1992** | 148589 | 272807 | 58163 | 41630 | 35443 | 39425 | 24772 | 14802 | 9285 | 4580 | 6542 |
| **1993** | 245438 | 198416 | 363863 | 25640 | 24070 | 22162 | 26761 | 15803 | 8993 | 5229 | 5114 |
| **1994** | 317133 | 390736 | 70546 | 238215 | 6560 | 5128 | 5043 | 10051 | 7057 | 4437 | 5353 |
| **1995** | 328587 | 312227 | 400432 | 14770 | 159916 | 2860 | 1693 | 1391 | 3957 | 3168 | 4866 |
| **1996** | 209818 | 244036 | 48437 | 376918 | 2379 | 57568 | 993 | 573 | 403 | 1434 | 2997 |
| **1997** | 296727 | 328383 | 149779 | 8703 | 354794 | 1765 | 47585 | 646 | 342 | 219 | 4009 |
| **1998** | 347002 | 405345 | 265532 | 109928 | 1351 | 338306 | 1845 | 51328 | 563 | 183 | 677 |
| **1999** | 240073 | 375829 | 149723 | 189417 | 66482 | 154 | 186645 | 1298 | 36747 | 340 | 250 |

Table 20. Estimated abundance (thousands) from the VPA which used the recruitment-and-mortality modulated catch at age, five indices of abundance and the year-constant index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 1123.4 | 960.4 | 665.2 | 416.8 | 257.4 | 162.2 | 97.8 | 50.8 | 30.2 | 15.0 | 18.4 |
| 1987 | 921.3 | 813.0 | 584.9 | 393.7 | 232.6 | 142.3 | 91.6 | 54.7 | 25.4 | 15.6 | 15.3 |
| 1988 | 651.6 | 682.5 | 538.7 | 372.4 | 249.8 | 143.9 | 88.0 | 57.5 | 33.9 | 14.5 | 18.2 |
| 1989 | 552.1 | 429.6 | 423.3 | 319.2 | 227.2 | 156.8 | 88.6 | 53.2 | 34.1 | 18.8 | 15.0 |
| 1990 | 468.9 | 342.0 | 241.2 | 284.8 | 201.1 | 128.2 | 82.1 | 41.9 | 25.7 | 17.6 | 17.3 |
| 1991 | 2989.5 | 328.2 | 197.4 | 149.3 | 193.4 | 130.3 | 78.0 | 46.9 | 21.9 | 13.2 | 18.6 |
| 1992 | 568.6 | 2401.2 | 119.3 | 87.7 | 76.3 | 103.8 | 67.7 | 41.4 | 25.2 | 11.0 | 15.8 |
| 1993 | 5144.1 | 352.3 | 1814.3 | 49.3 | 37.3 | 33.1 | 53.1 | 35.5 | 22.0 | 13.1 | 12.8 |
| 1994 | 809.5 | 4200.2 | 121.3 | 1225.3 | 18.9 | 10.1 | 8.2 | 21.1 | 16.0 | 10.6 | 12.8 |
| 1995 | 1836.1 | 404.8 | 3253.5 | 39.8 | 834.5 | 10.2 | 4.0 | 2.5 | 8.9 | 7.3 | 11.2 |
| 1996 | 2924.8 | 1276.6 | 64.7 | 2429.8 | 20.7 | 570.5 | 6.2 | 1.8 | 0.9 | 4.1 | 8.5 |
| 1997 | | 2323.1 | 873.2 | 11.6 | 1742.8 | 15.6 | 437.7 | 4.4 | 1.1 | 0.4 | 6.7 |
| 1998 | | | 1695.8 | 613.1 | 2.1 | 1172.2 | 11.8 | 332.7 | 3.2 | 0.6 | 2.2 |
| 1999 | | | | 1214.0 | 426.1 | 0.6 | 696.8 | 8.4 | 238.9 | 2.2 | 1.6 |
| 2000 | | | | | 869.8 | 305.3 | 0.4 | 427.5 | 6.1 | 171.6 | 2.8 |

Table 21. Estimated fishing mortality rates from the VPA which used the recruitment-and-mortality modulated catch at age, five indices of abundance and the year-constant index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 0.173 | 0.346 | 0.374 | 0.433 | 0.442 | 0.421 | 0.431 | 0.543 | 0.512 | 0.631 | 0.631 |
| 1987 | 0.15 | 0.262 | 0.302 | 0.305 | 0.33 | 0.331 | 0.316 | 0.33 | 0.41 | 0.375 | 0.375 |
| 1988 | 0.267 | 0.328 | 0.373 | 0.344 | 0.315 | 0.335 | 0.353 | 0.372 | 0.441 | 0.633 | 0.633 |
| 1989 | 0.329 | 0.427 | 0.246 | 0.312 | 0.422 | 0.497 | 0.599 | 0.578 | 0.512 | 0.518 | 0.518 |
| 1990 | 0.207 | 0.4 | 0.329 | 0.237 | 0.284 | 0.347 | 0.41 | 0.498 | 0.513 | 0.477 | 0.477 |
| 1991 | 0.069 | 0.862 | 0.661 | 0.522 | 0.472 | 0.504 | 0.485 | 0.473 | 0.536 | 0.554 | 0.554 |
| 1992 | 0.329 | 0.13 | 0.734 | 0.706 | 0.685 | 0.521 | 0.497 | 0.483 | 0.502 | 0.586 | 0.586 |
| 1993 | 0.053 | 0.916 | 0.242 | 0.809 | 1.159 | 1.24 | 0.772 | 0.647 | 0.576 | 0.556 | 0.556 |
| 1994 | 0.543 | 0.105 | 0.964 | 0.234 | 0.465 | 0.784 | 1.052 | 0.71 | 0.638 | 0.592 | 0.592 |
| 1995 | 0.213 | 1.683 | 0.142 | 0.506 | 0.23 | 0.357 | 0.612 | 0.912 | 0.64 | 0.627 | 0.627 |
| 1996 | 0.08 | 0.23 | 1.565 | 0.182 | 0.132 | 0.115 | 0.19 | 0.404 | 0.699 | 0.476 | 0.476 |
| 1997 | | 0.165 | 0.204 | 1.561 | 0.247 | 0.13 | 0.124 | 0.173 | 0.424 | 1.012 | 1.012 |
| 1998 | | | 0.184 | 0.214 | 1.147 | 0.37 | 0.184 | 0.181 | 0.211 | 0.397 | 0.397 |
| 1999 | | | | 0.183 | 0.183 | 0.339 | 0.339 | 0.181 | 0.181 | 0.181 | 0.181 |

Table 22. Catch at age derived with the recruitment-and-mortality modulated growth method (Goodyear 1997) iterated 5 times, the Cass-Calay *et al.* growth equation, M of 0.15, the young of the year index from sea grass tows with an average for years before 1991, year variable selectivity and five indices in the VPA**.**

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 165947 | 260937 | 193522 | 136980 | 86073 | 52235 | 32179 | 20058 | 11490 | 6777 | 8575 |
| **1987** | 119075 | 173528 | 141768 | 96679 | 61105 | 37489 | 23277 | 14466 | 8123 | 4685 | 4834 |
| **1988** | 141717 | 177090 | 156155 | 101290 | 63304 | 38265 | 24455 | 16707 | 11377 | 6501 | 8542 |
| **1989** | 143911 | 138685 | 86215 | 79541 | 72803 | 57475 | 37519 | 22037 | 12988 | 7304 | 6138 |
| **1990** | 81179 | 105365 | 61946 | 56129 | 46275 | 35324 | 26100 | 15497 | 9741 | 6328 | 6534 |
| **1991** | 184755 | 177230 | 91617 | 53969 | 67587 | 48438 | 28695 | 17132 | 8777 | 5424 | 7810 |
| **1992** | 148165 | 266598 | 64630 | 44201 | 31666 | 39028 | 25066 | 15260 | 9663 | 4801 | 6962 |
| **1993** | 244357 | 198328 | 352631 | 35573 | 28320 | 19615 | 26416 | 15901 | 9241 | 5496 | 5611 |
| **1994** | 316316 | 383518 | 74729 | 233808 | 11837 | 7884 | 5132 | 10174 | 6937 | 4367 | 5558 |
| **1995** | 327447 | 311596 | 390955 | 19481 | 160461 | 6183 | 3316 | 1829 | 4412 | 3241 | 4942 |
| **1996** | 209095 | 229714 | 49404 | 382987 | 5125 | 59793 | 2302 | 1320 | 696 | 1814 | 3306 |
| **1997** | 296024 | 320926 | 112876 | 9463 | 391687 | 4451 | 49852 | 1562 | 854 | 460 | 4800 |
| **1998** | 346027 | 413293 | 219915 | 51785 | 2015 | 427706 | 4732 | 52598 | 1462 | 632 | 1891 |
| **1999** | 238493 | 370357 | 193352 | 103942 | 19902 | 555 | 279611 | 3164 | 35671 | 899 | 1011 |

Table 23. Estimated abundance from the VPA which used the recruitment-and-mortality modulated catch at age, five indices of abundance and the year-constant index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 1156.9 | 985.7 | 684.5 | 426.1 | 263.2 | 166.6 | 101.2 | 52.7 | 31.8 | 16.1 | 20.4 |
| **1987** | 963.6 | 842.2 | 607.5 | 410.6 | 240.4 | 147.2 | 95.3 | 57.5 | 26.9 | 16.8 | 17.3 |
| **1988** | 644.3 | 719.2 | 564.6 | 392.0 | 264.1 | 150.5 | 92.1 | 60.5 | 36.1 | 15.6 | 20.5 |
| **1989** | 613.9 | 423.7 | 455.5 | 341.8 | 243.9 | 168.9 | 94.2 | 56.7 | 36.7 | 20.6 | 17.3 |
| **1990** | 606.2 | 395.5 | 236.8 | 312.4 | 220.8 | 142.8 | 92.4 | 46.6 | 28.5 | 19.6 | 20.2 |
| **1991** | 5326.4 | 446.7 | 243.1 | 146.6 | 217.0 | 147.2 | 90.3 | 55.4 | 25.8 | 15.6 | 22.4 |
| **1992** | 819.6 | 4413.3 | 221.3 | 124.9 | 76.5 | 124.4 | 82.1 | 51.2 | 31.9 | 14.1 | 20.5 |
| **1993** | 51803.6 | 568.5 | 3551.7 | 130.9 | 66.8 | 36.7 | 71.1 | 47.5 | 30.0 | 18.6 | 18.9 |
| **1994** | 896.4 | 44361.3 | 306.5 | 2730.6 | 79.8 | 31.4 | 13.6 | 36.9 | 26.3 | 17.3 | 22.0 |
| **1995** | 1020.1 | 480.1 | 37826.7 | 194.8 | 2133.8 | 57.7 | 19.8 | 7.0 | 22.4 | 16.2 | 24.7 |
| **1996** | 1545.0 | 576.1 | 128.5 | 32195.4 | 149.7 | 1688.0 | 44.0 | 13.9 | 4.3 | 15.2 | 27.6 |
| **1997** | | 1136.4 | 284.4 | 65.1 | 27355.9 | 124.1 | 1397.5 | 35.7 | 10.8 | 3.1 | 32.1 |
| **1998** | | | 682.0 | 140.9 | 47.3 | 23182.5 | 102.7 | 1156.6 | 29.3 | 8.5 | 25.4 |
| **1999** | | | | 384.2 | 73.6 | 38.8 | 19557.0 | 84.0 | 946.8 | 23.9 | 26.8 |
| **2000** | | | | | 234.8 | 44.9 | 32.9 | 16573.8 | 69.4 | 781.9 | 41.9 |

Table 24. Estimated fishing mortality rates from the VPA which used the recruitment-and-mortality modulated catch at age, five indices of abundance and the year-constant index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 0.167 | 0.334 | 0.361 | 0.422 | 0.431 | 0.409 | 0.416 | 0.523 | 0.489 | 0.597 | 0.597 |
| **1987** | 0.143 | 0.250 | 0.288 | 0.291 | 0.318 | 0.319 | 0.304 | 0.315 | 0.391 | 0.356 | 0.356 |
| **1988** | 0.269 | 0.307 | 0.352 | 0.325 | 0.297 | 0.318 | 0.335 | 0.351 | 0.412 | 0.588 | 0.588 |
| **1989** | 0.290 | 0.432 | 0.227 | 0.287 | 0.386 | 0.453 | 0.555 | 0.537 | 0.477 | 0.478 | 0.478 |
| **1990** | 0.155 | 0.336 | 0.329 | 0.214 | 0.255 | 0.309 | 0.361 | 0.441 | 0.456 | 0.425 | 0.425 |
| **1991** | 0.038 | 0.552 | 0.516 | 0.501 | 0.406 | 0.434 | 0.416 | 0.402 | 0.453 | 0.467 | 0.467 |
| **1992** | 0.216 | 0.067 | 0.375 | 0.476 | 0.584 | 0.410 | 0.396 | 0.385 | 0.392 | 0.453 | 0.453 |
| **1993** | 0.005 | 0.468 | 0.113 | 0.345 | 0.604 | 0.843 | 0.507 | 0.444 | 0.400 | 0.382 | 0.382 |
| **1994** | 0.474 | 0.009 | 0.303 | 0.097 | 0.174 | 0.314 | 0.517 | 0.351 | 0.333 | 0.316 | 0.316 |
| **1995** | 0.421 | 1.168 | 0.011 | 0.114 | 0.084 | 0.122 | 0.199 | 0.330 | 0.238 | 0.242 | 0.242 |
| **1996** | 0.157 | 0.556 | 0.530 | 0.013 | 0.038 | 0.039 | 0.058 | 0.107 | 0.190 | 0.138 | 0.138 |
| **1997** | | 0.361 | 0.552 | 0.170 | 0.016 | 0.039 | 0.039 | 0.048 | 0.089 | 0.175 | 0.175 |
| **1998** | | | 0.424 | 0.500 | 0.047 | 0.020 | 0.051 | 0.050 | 0.055 | 0.083 | 0.083 |
| **1999** | | | | 0.343 | 0.343 | 0.016 | 0.016 | 0.041 | 0.041 | 0.041 | 0.041 |

Table 25. Estimated abundance (thousands) from the VPA which used the age-length-key plus stochastic growth-curve-based catch-at-age, five indices of abundance and the year-constant index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 829.9 | 1524.3 | 1406.1 | 543.1 | 524.2 | 347.7 | 329.8 | 30.1 | 77.7 | 35.5 | 126.6 |
| 1987 | 1101.9 | 707.6 | 1252.2 | 886.6 | 303.5 | 277.0 | 241.1 | 227.7 | 15.3 | 48.0 | 111.8 |
| 1988 | 1132.8 | 944.1 | 553.7 | 906.9 | 557.0 | 222.1 | 166.8 | 161.1 | 180.5 | 8.2 | 118.8 |
| 1989 | 2106.7 | 957.8 | 747.0 | 299.7 | 597.1 | 370.7 | 151.1 | 105.2 | 114.4 | 148.8 | 81.9 |
| 1990 | 2516.2 | 1803.8 | 755.9 | 431.2 | 221.3 | 462.5 | 204.6 | 92.4 | 46.8 | 77.4 | 179.8 |
| 1991 | 2191.2 | 2157.0 | 1522.5 | 537.5 | 289.1 | 160.1 | 346.0 | 139.4 | 45.3 | 26.5 | 206.0 |
| 1992 | 2103.9 | 1876.8 | 1802.3 | 1055.6 | 342.8 | 228.1 | 79.5 | 232.9 | 88.9 | 28.0 | 185.5 |
| 1993 | 3192.4 | 1780.7 | 1568.8 | 1356.4 | 696.4 | 269.4 | 161.0 | 40.9 | 179.2 | 75.4 | 171.6 |
| 1994 | 3321.3 | 2692.7 | 1515.8 | 1133.3 | 856.1 | 414.8 | 206.2 | 117.9 | 21.6 | 141.3 | 200.6 |
| 1995 | 1599.0 | 2799.1 | 2287.4 | 1112.2 | 704.5 | 499.0 | 216.4 | 160.9 | 92.5 | 10.6 | 280.2 |
| 1996 | 2864.5 | 1322.8 | 2266.1 | 1648.0 | 775.9 | 394.5 | 321.2 | 98.5 | 122.3 | 75.4 | 237.4 |
| 1997 | | 2415.0 | 1108.3 | 1524.5 | 1183.8 | 604.3 | 311.1 | 253.7 | 78.4 | 100.9 | 261.6 |
| 1998 | | | 1987.1 | 484.2 | 1059.6 | 841.4 | 480.2 | 256.4 | 211.4 | 60.1 | 296.5 |
| 1999 | | | | 1476.7 | 202.5 | 577.0 | 465.2 | 383.7 | 206.1 | 172.3 | 294.3 |
| 2000 | | | | | 589.6 | 80.8 | 403.9 | 325.7 | 320.0 | 171.9 | 389.1 |

Table 26. Estimated fishing mortality rates from the VPA which used the age-length-key plus stochastic growth-curve-based catch-at-age, five indices of abundance and the year-constant index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986 | 0.009 | 0.047 | 0.311 | 0.432 | 0.488 | 0.216 | 0.220 | 0.526 | 0.332 | 0.222 | 0.222 |
| 1987 | 0.005 | 0.095 | 0.173 | 0.315 | 0.162 | 0.357 | 0.253 | 0.083 | 0.476 | 0.146 | 0.146 |
| 1988 | 0.018 | 0.084 | 0.464 | 0.268 | 0.257 | 0.235 | 0.311 | 0.192 | 0.043 | 0.288 | 0.288 |
| 1989 | 0.005 | 0.087 | 0.400 | 0.153 | 0.106 | 0.444 | 0.342 | 0.659 | 0.241 | 0.099 | 0.099 |
| 1990 | 0.004 | 0.020 | 0.191 | 0.250 | 0.173 | 0.140 | 0.234 | 0.562 | 0.419 | 0.072 | 0.072 |
| 1991 | 0.005 | 0.030 | 0.216 | 0.300 | 0.087 | 0.551 | 0.246 | 0.300 | 0.332 | 0.076 | 0.076 |
| 1992 | 0.017 | 0.029 | 0.134 | 0.266 | 0.091 | 0.199 | 0.515 | 0.112 | 0.014 | 0.068 | 0.068 |
| 1993 | 0.020 | 0.011 | 0.175 | 0.310 | 0.368 | 0.117 | 0.162 | 0.489 | 0.088 | 0.058 | 0.058 |
| 1994 | 0.021 | 0.013 | 0.160 | 0.325 | 0.390 | 0.501 | 0.098 | 0.093 | 0.560 | 0.049 | 0.049 |
| 1995 | 0.040 | 0.061 | 0.178 | 0.210 | 0.430 | 0.290 | 0.637 | 0.125 | 0.054 | 0.053 | 0.053 |
| 1996 | 0.021 | 0.027 | 0.246 | 0.181 | 0.100 | 0.087 | 0.086 | 0.078 | 0.042 | 0.029 | 0.029 |
| 1997 | | 0.045 | 0.678 | 0.214 | 0.191 | 0.080 | 0.044 | 0.032 | 0.116 | 0.051 | 0.051 |
| 1998 | | | 0.147 | 0.722 | 0.458 | 0.443 | 0.074 | 0.068 | 0.055 | 0.042 | 0.042 |
| 1999 | | | | 0.768 | 0.768 | 0.207 | 0.207 | 0.032 | 0.032 | 0.032 | 0.032 |

Table 27. Estimated abundance (thousands) from the sensitivity VPA which used the age-length-key plus stochastic growth-curve-based catch-at-age, five indices of abundance and the year-constant index selectivity assumption and which estimated 1999 fishing mortality rates on ages 0, 1, 2, 4 and 6 years.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 804.7 | 1254.2 | 1288.3 | 507.9 | 497.4 | 285.9 | 237.6 | 26.8 | 63.4 | 28.2 | 100.5 |
| **1987** | 916.1 | 685.9 | 1019.8 | 785.4 | 273.2 | 254.0 | 188.0 | 148.4 | 12.5 | 35.7 | 83.1 |
| **1988** | 877.6 | 784.2 | 535.0 | 707.0 | 470.0 | 196.0 | 147.1 | 115.5 | 112.2 | 5.8 | 83.6 |
| **1989** | 1944.4 | 738.2 | 609.4 | 283.7 | 425.2 | 295.9 | 128.7 | 88.2 | 75.2 | 90.0 | 49.6 |
| **1990** | 2036.1 | 1664.2 | 566.9 | 313.0 | 207.5 | 314.5 | 140.4 | 73.1 | 32.3 | 43.6 | 101.4 |
| **1991** | 1697.1 | 1743.8 | 1402.3 | 374.9 | 187.5 | 148.3 | 218.7 | 84.2 | 28.9 | 14.1 | 109.5 |
| **1992** | 1315.9 | 1451.5 | 1446.6 | 952.2 | 203.1 | 140.7 | 69.3 | 123.5 | 41.5 | 13.8 | 91.7 |
| **1993** | 3999.4 | 1102.5 | 1202.7 | 1050.4 | 607.5 | 149.1 | 85.8 | 32.2 | 85.1 | 34.6 | 78.8 |
| **1994** | 4182.9 | 3387.3 | 932.0 | 818.4 | 593.1 | 338.4 | 102.7 | 53.2 | 14.1 | 60.3 | 85.6 |
| **1995** | 1607.2 | 3540.7 | 2885.3 | 610.0 | 434.0 | 273.3 | 150.9 | 71.9 | 36.8 | 4.2 | 111.5 |
| **1996** | 2915.0 | 1329.8 | 2904.4 | 2162.4 | 344.2 | 162.7 | 127.4 | 42.6 | 45.7 | 27.6 | 86.7 |
| **1997** | | 2458.4 | 1114.3 | 2073.6 | 1626.5 | 232.8 | 111.7 | 86.9 | 30.4 | 35.0 | 90.7 |
| **1998** | | | 2024.6 | 489.4 | 1532.0 | 1222.3 | 160.5 | 84.7 | 67.9 | 18.8 | 92.7 |
| **1999** | | | | 1508.9 | 206.9 | 982.9 | 792.5 | 108.6 | 58.3 | 48.8 | 83.3 |
| **2000** | | | | | 617.2 | 84.6 | 753.2 | 607.3 | 83.3 | 44.7 | 101.2 |

Table 28. Estimated fishing mortality rates from the sensitivity VPA which used the age-length-key plus stochastic growth-curve-based catch-at-age, five indices of abundance and the year-constant index selectivity assumption and which estimated 1999 fishing mortality rates on ages 0, 1, 2, 4 and 6 years.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 0.010 | 0.057 | 0.345 | 0.470 | 0.522 | 0.269 | 0.321 | 0.614 | 0.425 | 0.288 | 0.288 |
| **1987** | 0.005 | 0.099 | 0.216 | 0.363 | 0.182 | 0.397 | 0.338 | 0.130 | 0.623 | 0.202 | 0.202 |
| **1988** | 0.023 | 0.102 | 0.484 | 0.358 | 0.313 | 0.271 | 0.361 | 0.279 | 0.070 | 0.439 | 0.439 |
| **1989** | 0.006 | 0.114 | 0.516 | 0.163 | 0.151 | 0.595 | 0.415 | 0.854 | 0.394 | 0.170 | 0.170 |
| **1990** | 0.005 | 0.021 | 0.263 | 0.362 | 0.186 | 0.213 | 0.361 | 0.780 | 0.681 | 0.132 | 0.132 |
| **1991** | 0.006 | 0.037 | 0.237 | 0.463 | 0.137 | 0.611 | 0.422 | 0.558 | 0.585 | 0.148 | 0.148 |
| **1992** | 0.027 | 0.038 | 0.170 | 0.299 | 0.159 | 0.344 | 0.618 | 0.222 | 0.031 | 0.143 | 0.143 |
| **1993** | 0.016 | 0.018 | 0.235 | 0.422 | 0.435 | 0.223 | 0.328 | 0.674 | 0.195 | 0.131 | 0.131 |
| **1994** | 0.017 | 0.010 | 0.274 | 0.484 | 0.625 | 0.657 | 0.207 | 0.218 | 1.055 | 0.119 | 0.119 |
| **1995** | 0.039 | 0.048 | 0.138 | 0.422 | 0.831 | 0.613 | 1.114 | 0.304 | 0.140 | 0.138 | 0.138 |
| **1996** | 0.020 | 0.027 | 0.187 | 0.135 | 0.241 | 0.226 | 0.233 | 0.189 | 0.117 | 0.082 | 0.082 |
| **1997** | | 0.044 | 0.673 | 0.153 | 0.136 | 0.222 | 0.126 | 0.097 | 0.330 | 0.154 | 0.154 |
| **1998** | | | 0.144 | 0.711 | 0.294 | 0.283 | 0.240 | 0.223 | 0.180 | 0.141 | 0.141 |
| **1999** | | | | 0.744 | 0.744 | 0.116 | 0.116 | 0.116 | 0.116 | 0.116 | 0.116 |

Table 29. Estimated abundance (thousands) from the VPA which used the age-length-key plus stochastic growth-curve-based catch-at-age, five indices of abundance and the year-variable index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 808.8 | 1297.8 | 1307.4 | 513.6 | 501.8 | 295.9 | 252.5 | 27.3 | 65.7 | 29.4 | 104.7 |
| **1987** | 946.1 | 689.4 | 1057.4 | 801.7 | 278.1 | 257.8 | 196.6 | 161.2 | 12.9 | 37.6 | 87.8 |
| **1988** | 918.8 | 810.0 | 538.0 | 739.3 | 484.1 | 200.2 | 150.2 | 122.8 | 123.2 | 6.2 | 89.2 |
| **1989** | 1970.8 | 773.6 | 631.6 | 286.3 | 452.9 | 308.0 | 132.3 | 91.0 | 81.5 | 99.5 | 54.8 |
| **1990** | 2113.8 | 1686.9 | 597.4 | 332.1 | 209.7 | 338.4 | 150.8 | 76.2 | 34.7 | 49.1 | 114.1 |
| **1991** | 1777.1 | 1810.6 | 1421.8 | 401.2 | 203.9 | 150.2 | 239.2 | 93.1 | 31.5 | 16.1 | 125.0 |
| **1992** | 1443.1 | 1520.3 | 1504.1 | 969.0 | 225.7 | 154.8 | 70.9 | 141.1 | 49.1 | 16.1 | 106.8 |
| **1993** | 2725.3 | 1212.0 | 1261.9 | 1099.9 | 622.0 | 168.5 | 97.9 | 33.6 | 100.3 | 41.2 | 93.8 |
| **1994** | 2822.5 | 2290.7 | 1026.2 | 869.4 | 635.6 | 350.8 | 119.4 | 63.6 | 15.3 | 73.3 | 104.1 |
| **1995** | 1728.6 | 2369.8 | 1941.4 | 691.1 | 477.8 | 309.7 | 161.5 | 86.3 | 45.8 | 5.3 | 138.7 |
| **1996** | 3669.5 | 1434.3 | 1896.6 | 1350.3 | 413.8 | 200.1 | 158.7 | 51.7 | 58.0 | 35.3 | 111.0 |
| **1997** | | 3107.8 | 1204.2 | 1206.8 | 927.7 | 292.7 | 143.8 | 113.8 | 38.1 | 45.6 | 118.2 |
| **1998** | | | 2583.5 | 566.4 | 786.3 | 621.1 | 212.0 | 112.4 | 91.0 | 25.5 | 125.5 |
| **1999** | | | | 1989.8 | 272.8 | 342.7 | 276.3 | 153.0 | 82.1 | 68.7 | 117.3 |
| **2000** | | | | | 1029.2 | 141.1 | 202.4 | 163.2 | 121.4 | 65.2 | 147.6 |

Table 30. Estimated fishing mortality rates from the VPA which used the age-length-key plus stochastic growth-curve-based catch-at-age, five indices of abundance and the year-variable index selectivity assumption.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9 | Age 10+ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1986** | 0.010 | 0.055 | 0.339 | 0.463 | 0.516 | 0.259 | 0.299 | 0.598 | 0.407 | 0.274 | 0.274 |
| **1987** | 0.005 | 0.098 | 0.208 | 0.355 | 0.179 | 0.390 | 0.320 | 0.119 | 0.593 | 0.190 | 0.190 |
| **1988** | 0.022 | 0.099 | 0.481 | 0.340 | 0.302 | 0.264 | 0.352 | 0.260 | 0.064 | 0.405 | 0.405 |
| **1989** | 0.006 | 0.109 | 0.493 | 0.161 | 0.142 | 0.564 | 0.401 | 0.814 | 0.357 | 0.152 | 0.152 |
| **1990** | 0.005 | 0.021 | 0.248 | 0.338 | 0.184 | 0.197 | 0.332 | 0.733 | 0.618 | 0.116 | 0.116 |
| **1991** | 0.006 | 0.035 | 0.233 | 0.425 | 0.126 | 0.600 | 0.378 | 0.490 | 0.521 | 0.128 | 0.128 |
| **1992** | 0.025 | 0.036 | 0.163 | 0.293 | 0.142 | 0.308 | 0.598 | 0.192 | 0.026 | 0.121 | 0.121 |
| **1993** | 0.024 | 0.016 | 0.223 | 0.398 | 0.423 | 0.195 | 0.281 | 0.635 | 0.163 | 0.109 | 0.109 |
| **1994** | 0.025 | 0.015 | 0.245 | 0.449 | 0.569 | 0.625 | 0.175 | 0.179 | 0.920 | 0.096 | 0.096 |
| **1995** | 0.037 | 0.073 | 0.213 | 0.363 | 0.720 | 0.519 | 0.990 | 0.246 | 0.111 | 0.110 | 0.110 |
| **1996** | 0.016 | 0.025 | 0.302 | 0.225 | 0.196 | 0.180 | 0.183 | 0.154 | 0.091 | 0.063 | 0.063 |
| **1997** | | 0.035 | 0.604 | 0.278 | 0.251 | 0.172 | 0.097 | 0.073 | 0.254 | 0.116 | 0.116 |
| **1998** | | | 0.111 | 0.580 | 0.681 | 0.660 | 0.176 | 0.163 | 0.131 | 0.102 | 0.102 |
| **1999** | | | | 0.509 | 0.509 | 0.376 | 0.376 | 0.081 | 0.081 | 0.081 | 0.081 |

Table 31. Median and 80% empirical confidence intervals about current status and management reference points for Gulf of Mexico gag estimated from 500 bootstraps of the VPA based on the recruitment-and-mortality modulated catch-at-age under the assumption that recruitment increases to the maximum estimated spawning stock size during 1986-1999. Long-term potential yields are in millions of pounds gutted weight, yield per recruit is in pounds gutted weight, SSB is in thousands of metric tons of mature ovaries, and male SSB is in thousands of pounds gutted weight of mature males.

| | Estimate | Bias-corrected Estimate | Range of 80% CI |
|---|---|---|---|
| SSB 2000 / SSB $F_{30\%}$ | 0.695 | 0.746 | 0.161 |
| SSB 2000 / SSB $F_{max}$ | 0.322 | 0.346 | 0.0883 |
| F 1997-1999 (geometric mean) / $F_{30\%}$ | 0.986 | 0.931 | 0.792 |
| F 1997-1999 (geometric mean) / $F_{max}$ | 3.00 | 2.88 | 2.68 |
| | | | |
| $F_{30\%}$ SPR | 0.423 | 0.319 | 0.742 |
| Yield at $F_{30\%}$ | 7.45 | 6.29 | 6.34 |
| Y/R at $F_{30\%}$ | 2.01 | 2.04 | 0.457 |
| S/R at $F_{30\%}$ | 286 | 287 | 0.477 |
| SSB at $F_{30\%}$ | 1.06 | 0.902 | 0.741 |
| Male SSB at $F_{30\%}$ / Male SSB at $F_0$ | 0.0135 | | |
| | | | |
| $F_{40\%}$ SPR | 0.307 | 0.233 | 0.497 |
| Yield at $F_{40\%}$ | 9.19 | 7.78 | 8.52 |
| Y/R at $F_{40\%}$ | 2.48 | 2.52 | 0.783 |
| S/R at $F_{40\%}$ | 382 | 382 | 0.663 |
| SSB at $F_{40\%}$ | 1.41 | 1.20 | 0.987 |
| Male SSB at $F_{40\%}$ / Male SSB at $F_0$ | 0.0320 | | |
| | | | |
| F at maximum Y/R | 0.139 | 0.0980 | 0.128 |
| Yield at $F_{max}$ | 11.3 | 9.63 | 13.1 |
| Y/R maximum | 3.06 | 3.12 | 1.72 |
| S/R at $F_{max}$ | 618 | 623 | 146 |
| SPR at $F_{max}$ | 0.649 | 0.654 | 0.153 |
| SSB at $F_{max}$ | 2.29 | 1.94 | 2.05 |
| Male SSB at $F_{max}$ / Male SSB at $F_0$ | 0.155 | | |

Table 32. Median and 80% empirical confidence intervals about current status and management reference points for Gulf of Mexico gag estimated from 500 bootstraps of the VPA based on the recruitment-and-mortality modulated catch-at-age under the assumption that recruitment would equal the historical average recruitment when spawning stock size equaled or exceeded the minimum observed in 1986-1999. Long-term potential yields are in millions of pounds gutted weight, yield per recruit is in pounds gutted weight, SSB is in thousands of metric tons of mature ovaries, and male SSB is in thousands of pounds gutted weight of mature males.

| | Estimate | Bias-corrected Estimate | Range of 80% CI |
|---|---|---|---|
| SSB 2000 / SSB $F_{30\%}$ | 1.45 | 1.36 | 1.25 |
| SSB 2000 / SSB $F_{max}$ | 0.710 | 0.675 | 0.584 |
| F 1997-1999 (geometric mean) / $F_{30\%}$ | 1.48 | 1.41 | 1.17 |
| F 1997-1999 (geometric mean) / $F_{max}$ | 3.70 | 3.55 | 3.30 |
| | | | |
| $F_{30\%}$ SPR | 0.310 | 0.267 | 0.413 |
| Yield at $F_{30\%}$ | 2.28 | 2.27 | 0.886 |
| Y/R at $F_{30\%}$ | 1.92 | 1.94 | 0.567 |
| S/R at $F_{30\%}$ | 286 | 286 | 0.742 |
| SSB at $F_{30\%}$ | 0.340 | 0.340 | 0.0524 |
| Male SSB at $F_{30\%}$ / Male SSB at $F_0$ | 0.0275 | | |
| | | | |
| $F_{40\%}$ SPR | 0.232 | 0.201 | 0.293 |
| Yield at $F_{40\%}$ | 9.19 | 7.78 | 8.52 |
| Y/R at $F_{40\%}$ | 2.30 | 2.33 | 0.882 |
| S/R at $F_{40\%}$ | 382 | 382 | 1.06 |
| SSB at $F_{40\%}$ | 0.453 | 0.454 | 0.0692 |
| Male SSB at $F_{40\%}$ / Male SSB at $F_0$ | 0.0566 | | |
| | | | |
| F at maximum Y/R | 0.124 | 0.0977 | 0.0922 |
| Yield at $F_{max}$ | 11.3 | 9.63 | 13.1 |
| Y/R maximum | 2.67 | 2.72 | 1.64 |
| S/R at $F_{max}$ | 583 | 589 | 155 |
| SPR at $F_{max}$ | 0.613 | 0.618 | 0.163 |
| SSB at $F_{max}$ | 0.693 | 0.692 | 0.202 |
| Male SSB at $F_{max}$ / Male SSB at $F_0$ | 0.182 | | |

Table 33. Median and 80% empirical confidence intervals about current status and management reference points for Gulf of Mexico gag estimated from 500 bootstraps of the VPA based on the age-length-key plus stochastic growth catch-at-age under the assumptions (1) that index selectivity in the VPA varied by year and (2) that for the management bench marks and projections, recruitment would increase with spawning stock size to the maximum observed in 1986-1999. Long-term potential yields are in millions of pounds gutted weight, yield per recruit is in pounds gutted weight, SSB is in thousands of metric tons of mature ovaries, and male SSB is in thousands of pounds gutted weight of mature males.

| | Estimate | Bias-corrected Estimate | Range of 80% CI |
|---|---|---|---|
| SSB 2000 / SSB $F_{30\%}$ | 0.857 | 0.859 | 0.334 |
| SSB 2000 / SSB $F_{max}$ | 0.588 | 0.619 | 0.324 |
| F 1997-1999 (geometric mean) / $F_{30\%}$ | 0.773 | 0.968 | 0.650 |
| F 1997-1999 (geometric mean) / $F_{max}$ | 1.24 | 1.49 | 0.897 |
| | | | |
| $F_{30\%}$ SPR | 0.573 | 0.514 | 0.577 |
| Yield at $F_{30\%}$ | 8.50 | 4.80 | 98.8 |
| Y/R at $F_{30\%}$ | 2.84 | 2.77 | 0.765 |
| S/R at $F_{30\%}$ | 287 | 287 | 0.328 |
| SSB at $F_{30\%}$ | 0.859 | 0.415 | 8.97 |
| Male SSB at $F_{30\%}$ / Male SSB at $F_0$ | 0.0345 | | |
| | | | |
| $F_{40\%}$ SPR | 0.406 | 0.365 | 0.327 |
| Yield at $F_{40\%}$ | 9.04 | 4.55 | 114 |
| Y/R at $F_{40\%}$ | 3.02 | 2.92 | 1.06 |
| S/R at $F_{40\%}$ | 381 | 381 | 0.528 |
| SSB at $F_{40\%}$ | 1.14 | 0.551 | 11.9 |
| Male SSB at $F_{40\%}$ / Male SSB at $F_0$ | 0.0861 | | |
| | | | |
| F at maximum Y/R | 0.359 | 0.326 | 0.245 |
| Yield at $F_{max}$ | 9.07 | 4.68 | 128 |
| Y/R maximum | 3.03 | 2.93 | 1.29 |
| S/R at $F_{max}$ | 418 | 406 | 161 |
| SPR at $F_{max}$ | 0.439 | 0.427 | 0.169 |
| SSB at $F_{max}$ | 1.25 | 0.643 | 16.2 |
| Male SSB at $F_{max}$ / Male SSB at $F_0$ | 0.113 | | |

Table 34. Median and 80% empirical confidence intervals about current status and management reference points for Gulf of Mexico gag estimated from 500 bootstraps of the VPA based on the age-length-key plus stochastic growth catch-at-age under the assumptions (1) that index selectivity in the VPA varied by year and (2) that for the management bench marks and projections, recruitment would equal the historical average recruitment when spawning stock size equaled or exceeded the minimum observed in 1986-1999. Long-term potential yields are in millions of pounds gutted weight, yield per recruit is in pounds gutted weight, SSB is in thousands of metric tons of mature ovaries, and male SSB is in thousands of pounds gutted weight of mature males.

| | Estimate | Bias-corrected Estimate | Range of 80% CI |
|---|---|---|---|
| SSB 2000 / SSB $F_{30\%}$ | 1.27 | 0.683 | 7.06 |
| SSB 2000 / SSB $F_{max}$ | 0.871 | 0.450 | 4.03 |
| F 1997-1999 (geometric mean) / $F_{30\%}$ | 0.797 | 0.988 | 0.643 |
| F 1997-1999 (geometric mean) / $F_{max}$ | 1.27 | 1.52 | 0.895 |
| | | | |
| $F_{30\%}$ SPR | 0.556 | 0.509 | 0.459 |
| Yield at $F_{30\%}$ | 4.77 | 4.19 | 4.04 |
| Y/R at $F_{30\%}$ | 2.79 | 2.75 | 0.775 |
| S/R at $F_{30\%}$ | 286 | 286 | 0.350 |
| SSB at $F_{30\%}$ | 0.490 | 0.440 | 0.286 |
| Male SSB at $F_{30\%}$ / Male SSB at $F_0$ | 0.0368 | | |
| | | | |
| $F_{40\%}$ SPR | 0.396 | 0.361 | 0.273 |
| Yield at $F_{40\%}$ | 5.08 | 4.40 | 4.80 |
| Y/R at $F_{40\%}$ | 2.97 | 2.88 | 1.04 |
| S/R at $F_{40\%}$ | 381 | 381 | 0.539 |
| SSB at $F_{40\%}$ | 0.652 | 0.584 | 0.381 |
| Male SSB at $F_{40\%}$ / Male SSB at $F_0$ | 0.0894 | | |
| | | | |
| F at maximum Y/R | 0.349 | 0.320 | 0.242 |
| Yield at $F_{max}$ | 5.10 | 4.39 | 5.44 |
| Y/R maximum | 2.98 | 2.88 | 1.22 |
| S/R at $F_{max}$ | 418 | 407 | 156 |
| SPR at $F_{max}$ | 0.439 | 0.428 | 0.164 |
| SSB at $F_{max}$ | 0.716 | 0.642 | 0.639 |
| Male SSB at $F_{max}$ / Male SSB at $F_0$ | 0.117 | | |

Table 35. Median and 80% empirical confidence intervals about current status and management reference points for Gulf of Mexico gag estimated from 500 bootstraps of the VPA based on the age-length-key plus stochastic growth catch-at-age under the assumptions (1) that index selectivity in the VPA was constant over years and (2) that for the management bench marks and projections, recruitment would increase with spawning stock size to the maximum observed in 1986-1999. Long-term potential yields are in millions of pounds gutted weight, yield per recruit is in pounds gutted weight, SSB is in thousands of metric tons of mature ovaries, and male SSB is in thousands of pounds gutted weight of mature males.

| | Estimate | Bias-corrected Estimate | Range of 80% CI |
|---|---|---|---|
| SSB 2000 / SSB $F_{30\%}$ | 0.923 | 0.976 | 0.209 |
| SSB 2000 / SSB $F_{max}$ | 0.559 | 0.592 | 0.209 |
| F 1997-1999 (geometric mean) / $F_{30\%}$ | 0.664 | 0.683 | 0.489 |
| F 1997-1999 (geometric mean) / $F_{max}$ | 1.26 | 1.28 | 0.793 |
| | | | |
| $F_{30\%}$ SPR | 0.651 | 0.655 | 0.276 |
| Yield at $F_{30\%}$ | 11.4 | 9.46 | 13.0 |
| Y/R at $F_{30\%}$ | 2.85 | 2.83 | 0.568 |
| S/R at $F_{30\%}$ | 287 | 287 | 0.319 |
| SSB at $F_{30\%}$ | 1.15 | 0.953 | 1.21 |
| Male SSB at $F_{30\%}$ / Male SSB at $F_0$ | 0.0224 | | |
| | | | |
| $F_{40\%}$ SPR | 0.464 | 0.469 | 0.216 |
| Yield at $F_{40\%}$ | 12.5 | 10.5 | 14.8 |
| Y/R at $F_{40\%}$ | 3.13 | 3.11 | 0.793 |
| S/R at $F_{40\%}$ | 382 | 382 | 0.540 |
| SSB at $F_{40\%}$ | 1.53 | 1.27 | 1.61 |
| Male SSB at $F_{40\%}$ / Male SSB at $F_0$ | 0.0582 | | |
| | | | |
| F at maximum Y/R | 0.342 | 0.353 | 0.276 |
| Yield at $F_{max}$ | 12.9 | 10.7 | 15.8 |
| Y/R maximum | 3.21 | 3.19 | 0.979 |
| S/R at $F_{max}$ | 473 | 470 | 89.6 |
| SPR at $F_{max}$ | 0.497 | 0.493 | 0.0941 |
| SSB at $F_{max}$ | 1.89 | 1.62 | 2.10 |
| Male SSB at $F_{max}$ / Male SSB at $F_0$ | 0.114 | | |

Table 36. Median and 80% empirical confidence intervals about current status and management reference points for Gulf of Mexico gag estimated from 500 bootstraps of the VPA based on the age-length-key plus stochastic growth catch-at-age under the assumptions (1) that index selectivity in the VPA was constant over years and (2) that for the management bench marks and projections, recruitment would equal the historical average recruitment when spawning stock size equaled or exceeded the minimum observed in 1986-1999. Long-term potential yields are in millions of pounds gutted weight, yield per recruit is in pounds gutted weight, SSB is in thousands of metric tons of mature ovaries, and male SSB is in thousands of pounds gutted weight of mature males.

| | Estimate | Bias-corrected Estimate | Range of 80% CI |
|---|---|---|---|
| SSB 2000 / SSB $F_{30\%}$ | 1.58 | 1.38 | 1.43 |
| SSB 2000 / SSB $F_{max}$ | 0.954 | 0.816 | 0.825 |
| F 1997-1999 (geometric mean) / $F_{30\%}$ | 0.704 | 0.722 | 0.491 |
| F 1997-1999 (geometric mean) / $F_{max}$ | 1.32 | 1.34 | 0.789 |
| | | | |
| $F_{30\%}$ SPR | 0.614 | 0.618 | 0.255 |
| Yield at $F_{30\%}$ | 4.82 | 4.62 | 1.70 |
| Y/R at $F_{30\%}$ | 2.77 | 2.74 | 0.619 |
| S/R at $F_{30\%}$ | 286 | 286 | 0.348 |
| SSB at $F_{30\%}$ | 0.499 | 0.489 | 0.098 |
| Male SSB at $F_{30\%}$ / Male SSB at $F_0$ | 0.0255 | | |
| | | | |
| $F_{40\%}$ SPR | 0.441 | 0.447 | 0.201 |
| Yield at $F_{40\%}$ | 5.30 | 5.12 | 2.07 |
| Y/R at $F_{40\%}$ | 3.04 | 3.02 | 0.847 |
| S/R at $F_{40\%}$ | 382 | 382 | 0.551 |
| SSB at $F_{40\%}$ | 0.665 | 0.654 | 0.131 |
| Male SSB at $F_{40\%}$ / Male SSB at $F_0$ | 0.0634 | | |
| | | | |
| F at maximum Y/R | 0.327 | 0.336 | 0.257 |
| Yield at $F_{max}$ | 5.44 | 5.25 | 2.40 |
| Y/R maximum | 3.13 | 3.09 | 1.03 |
| S/R at $F_{max}$ | 473 | 470 | 88.9 |
| SPR at $F_{max}$ | 0.497 | 0.493 | 0.0933 |
| SSB at $F_{max}$ | 0.824 | 0.810 | 0.247 |
| Male SSB at $F_{max}$ / Male SSB at $F_0$ | 0.121 | | |

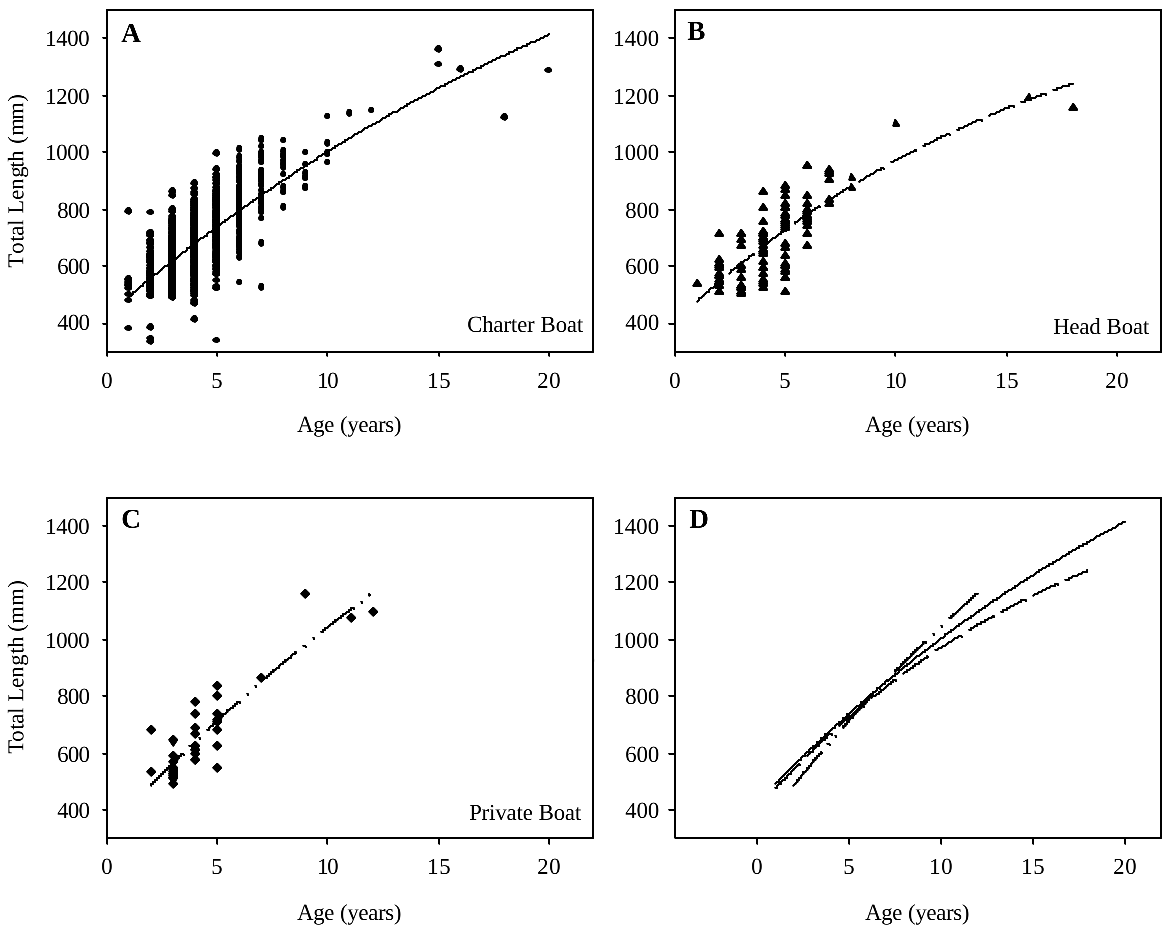



Figure 1. A comparison of length at age of gag caught by recreational fishing aboard charter (A), headboat (B), and private (C) vessels. Von Bertalanffy growth equations fit to the data are shown. The three curves are overlaid in panel D (charter=solid line, headboat=dashed line, and private = dash-dot-dot line).

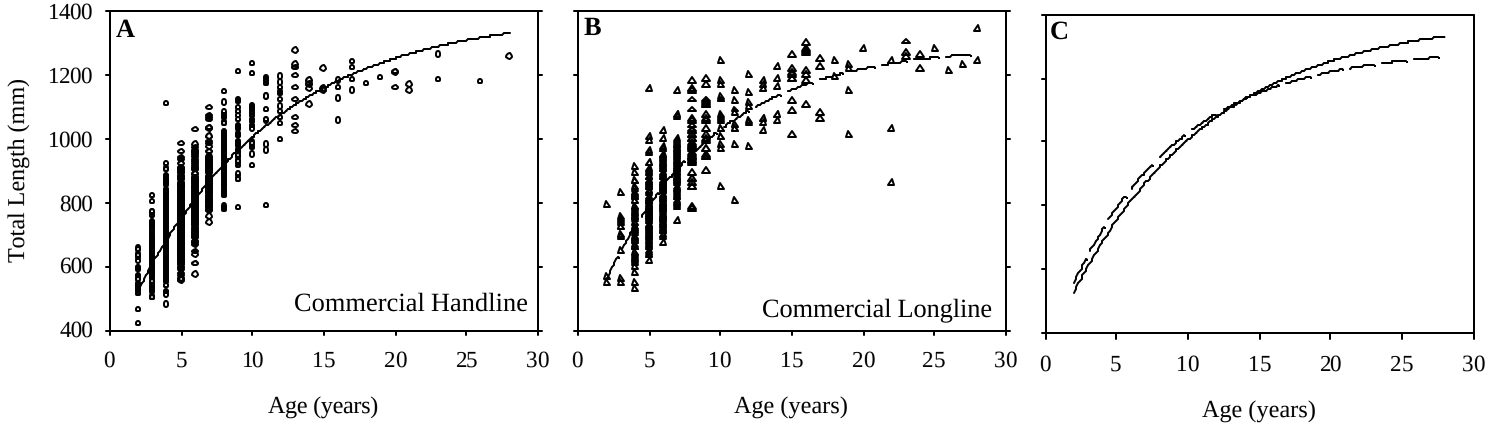



Figure 2. Comparison of the length at age of gag collected by handline (A) and longline (B) and fitted von Bertalanffy growth curves. In panel C the curves are overlaid (handline = solid and longline = dashed).

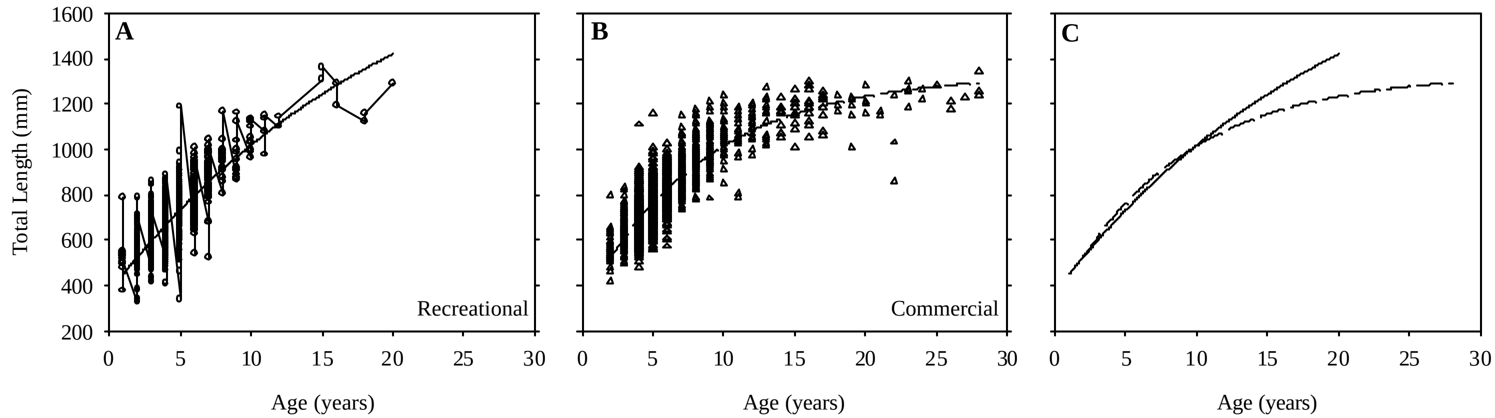



Figure 3. Comparison of length at age of gag caught in the recreational (A) and commercial (B) fisheries and fitted von Bertalanffy growth curves. In panel C the curves are overlaid (recreational = solid line and commercial = dashed line).

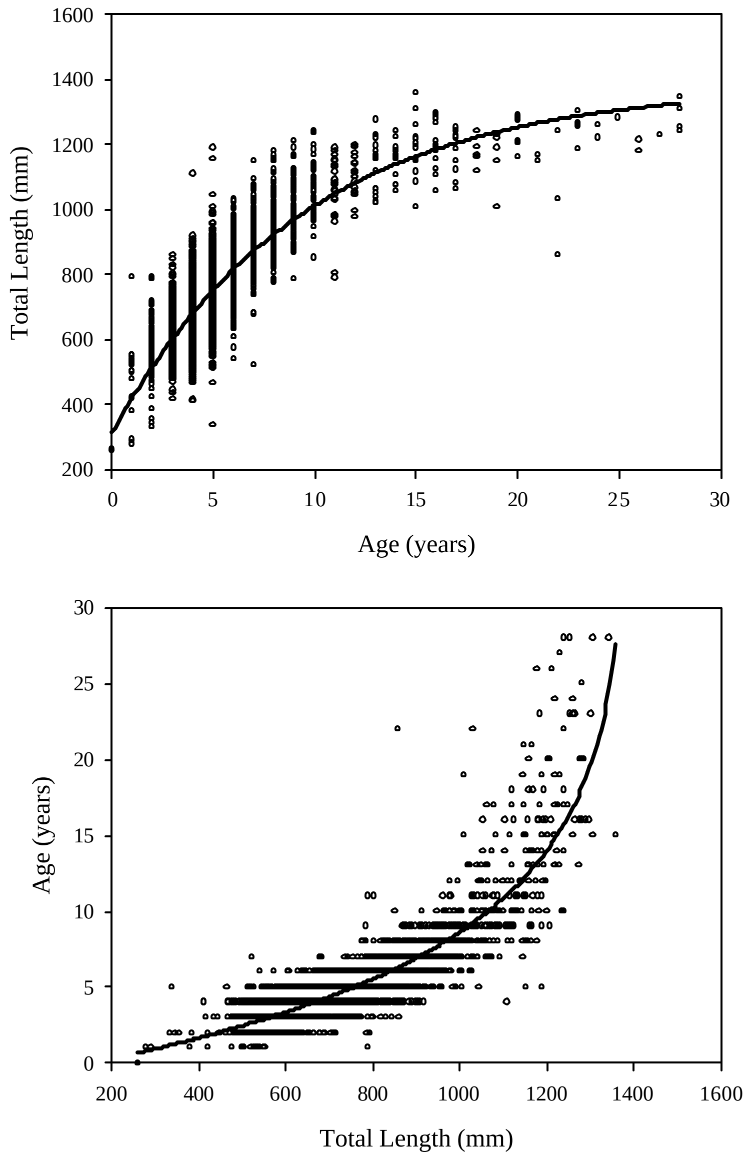
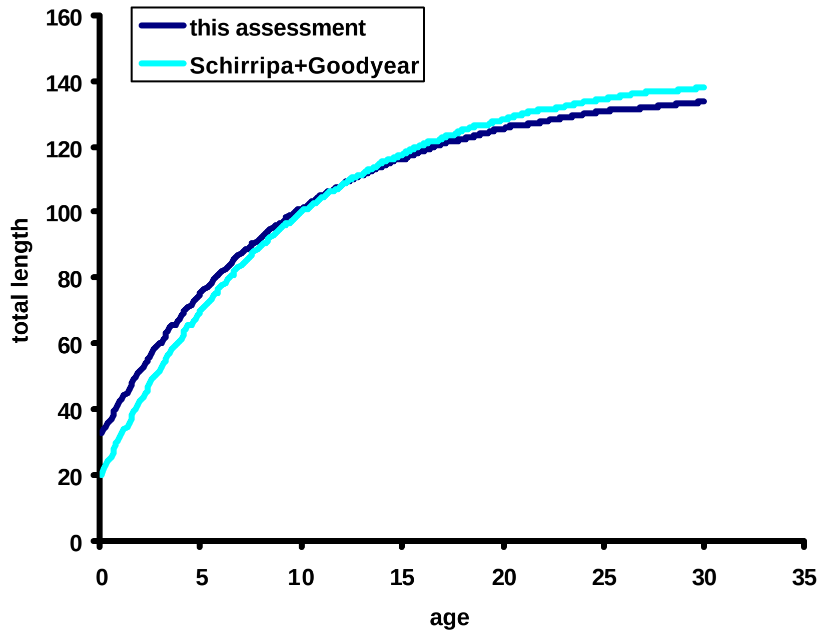



Figure 4. Von Bertalanffy (A) and inverted von Bertalanffy (B) growth curves fit to gag length-at-age data from recreational and commercial fisheries.



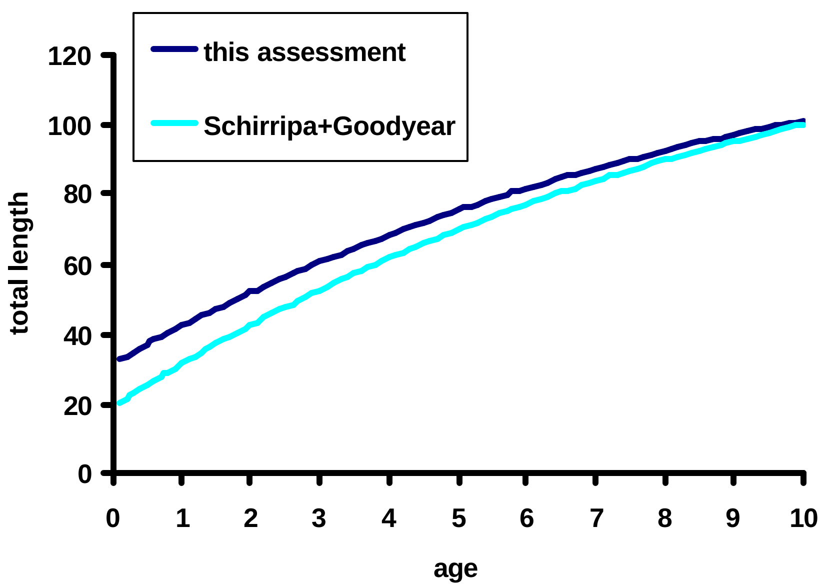




Figure 5. Comparison of the growth curve used for this assessment and the Schirripa and Goodyear (1994) curve used in the 1994 and 1997 assessments. Upper panel to age 30, lower to age 10.

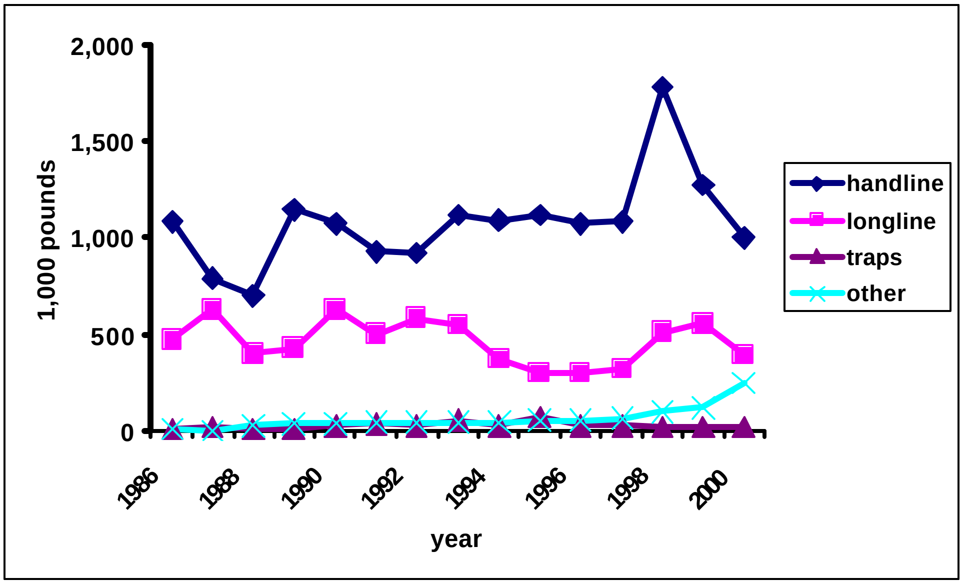



Figure 6. Commercial landings of calculated gag (including some black grouper and some unclassified groupers) by gear from U.S. Gulf of Mexico waters.

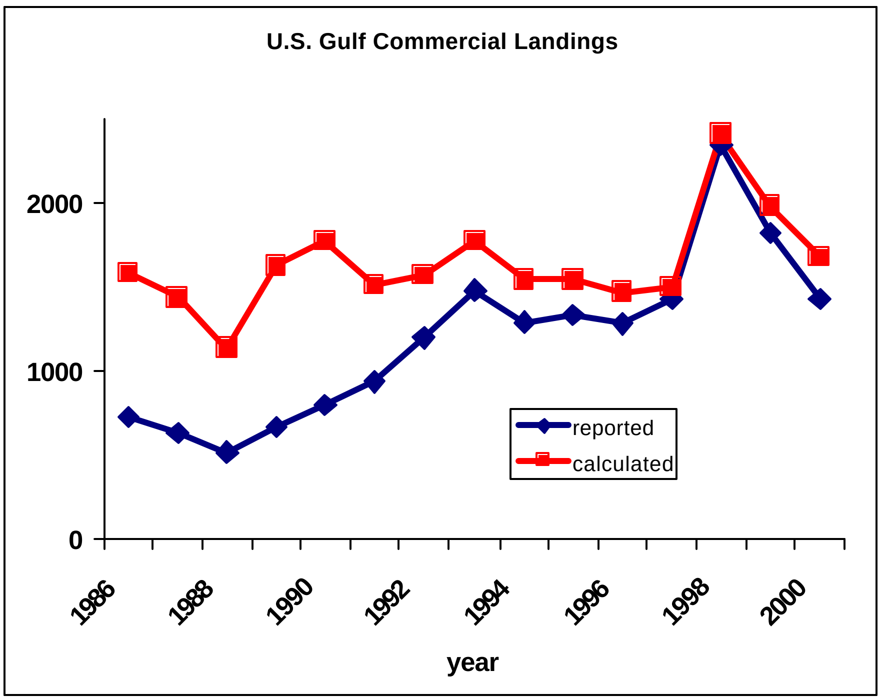



Figure 7. Reported and calculated gag from the U.S. Gulf of Mexico. Calculated gag is primarily derived from gag plus some black grouper

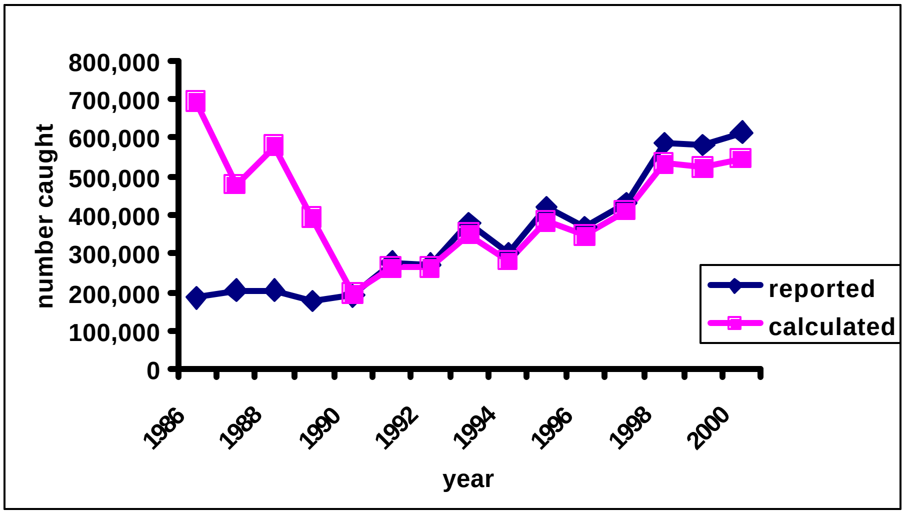


Figure 8. Recreational catches in number of fish reported to be gag and calculated to be gag. Calculated gag includes some black grouoper.

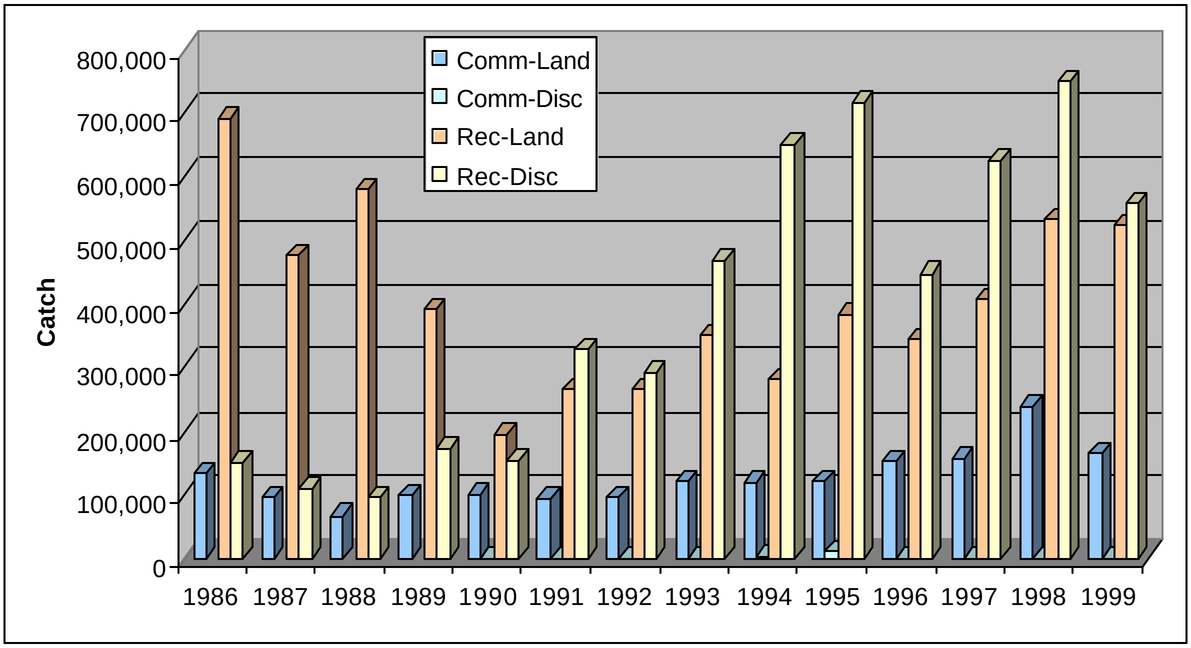



Figure 9. Calculated number of fish killed by recreational and commercial fisheries showing both landings and discards.

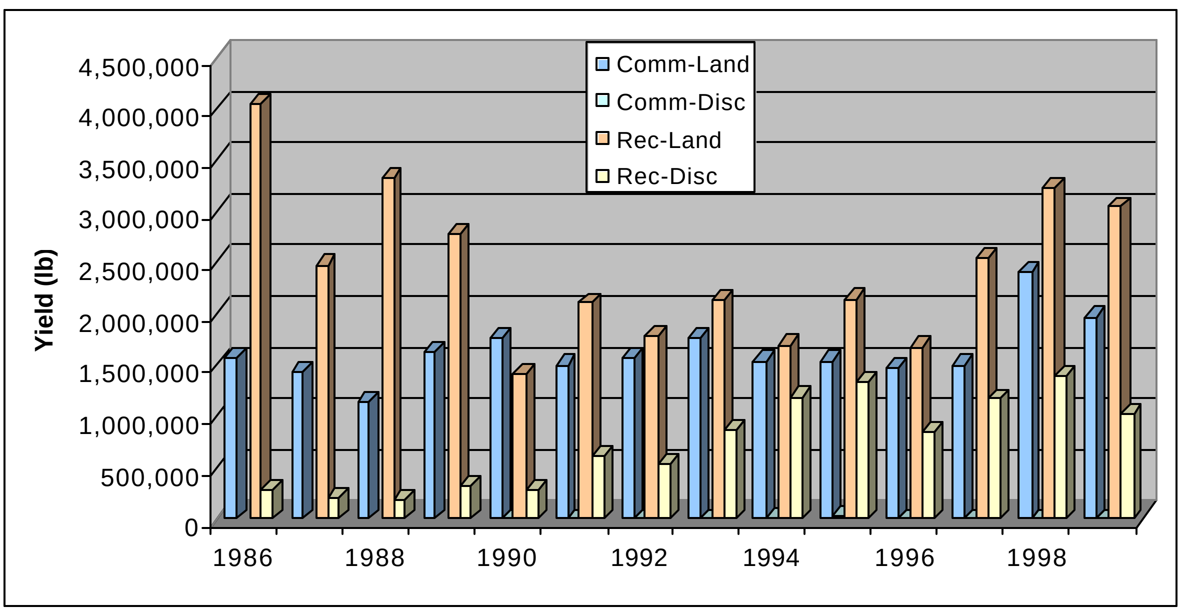
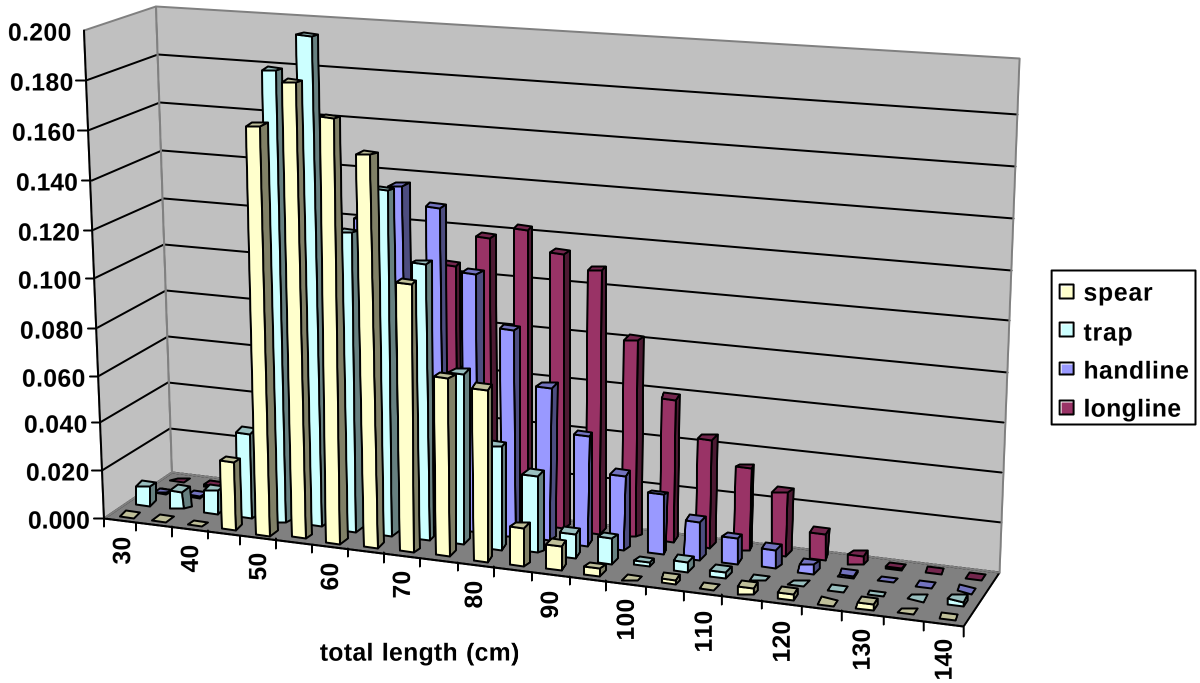



Figure 10. Calculated yield from the recreational and commercial fisheries showing both landings and discards.



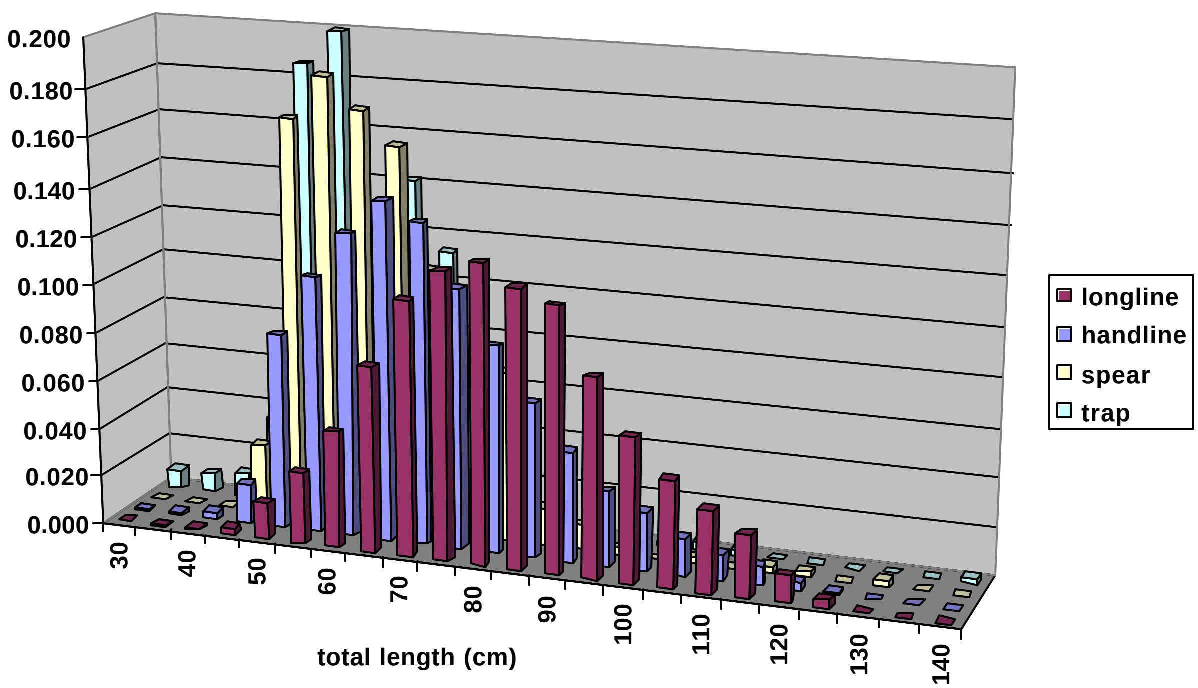
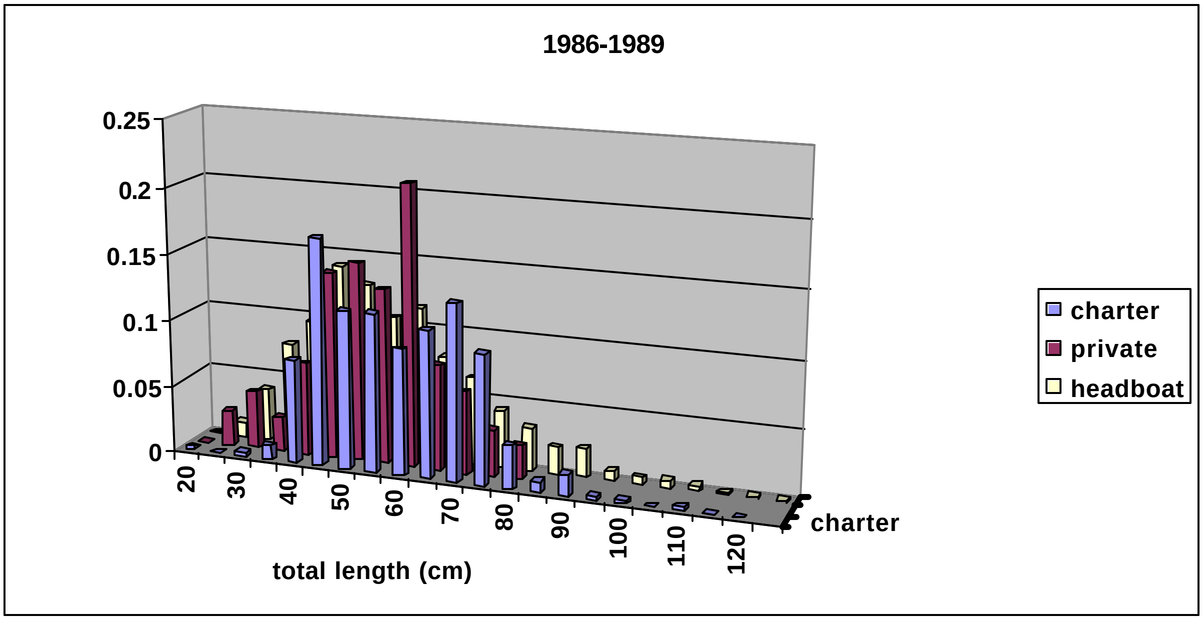




Figure 11. Commercial size composition by gear from 1986-1999.



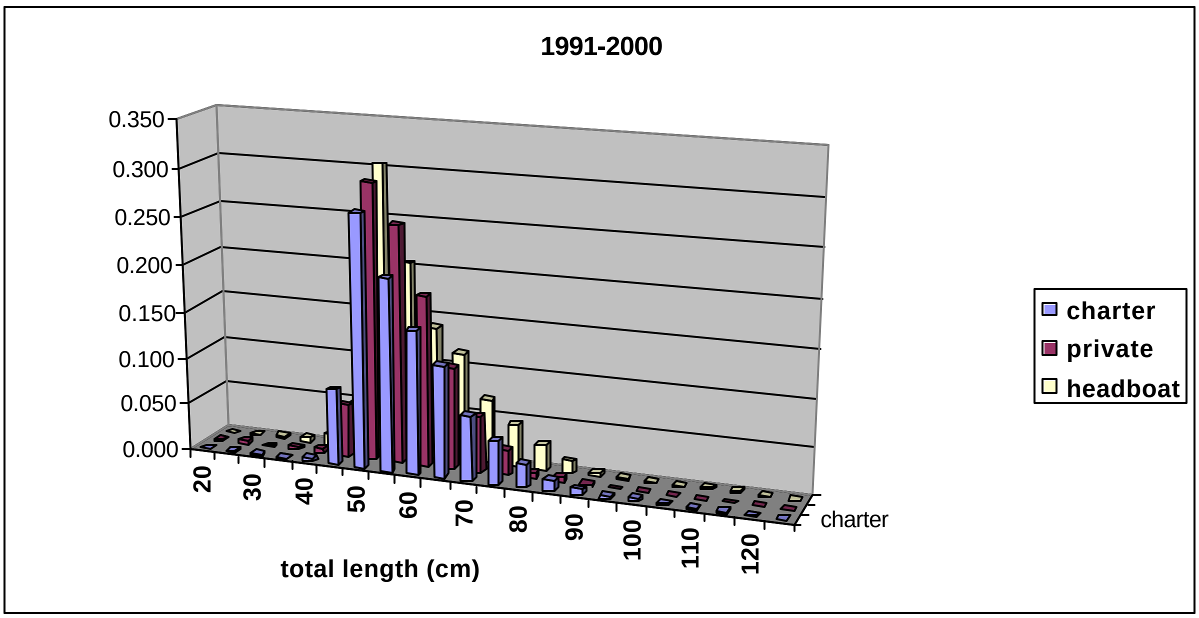




Figure 12. Size compostion of recreational fisheries during 1986-1989 and 1991-2000 (1999 for head boat).

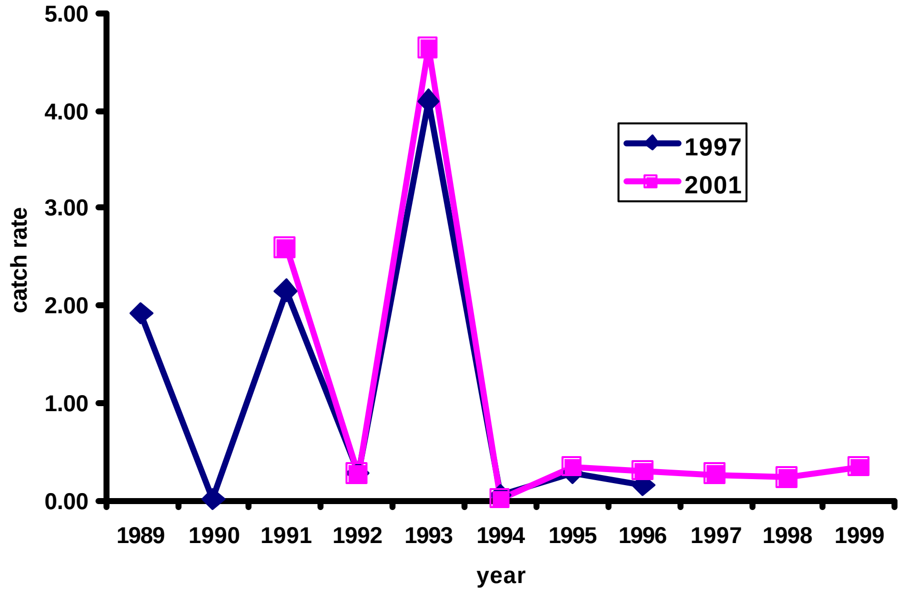



Figure 13. Indices of abundance from sea grass tows used for this assessment (2001) and the 1997 assessment by Schirripa and Legault.

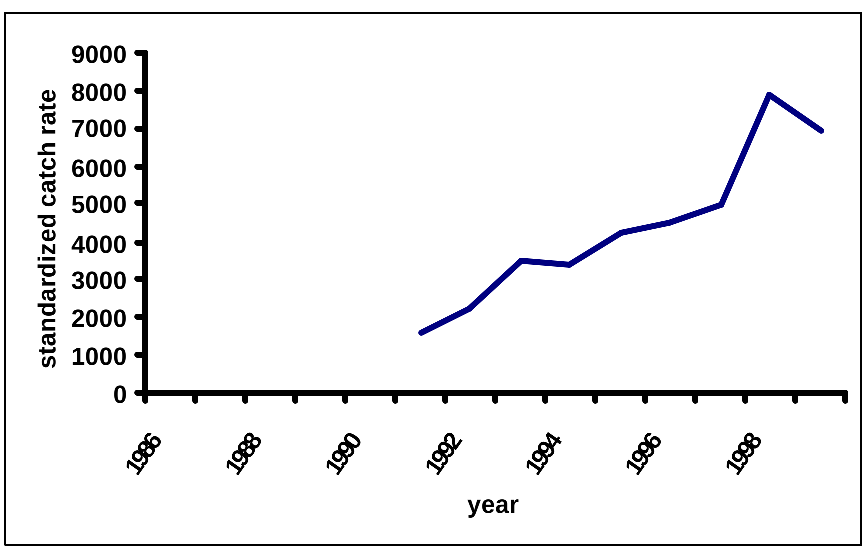



Figure 14. Standardized catch rates in pounds landed per day from handline effort in reef fish log book reports.

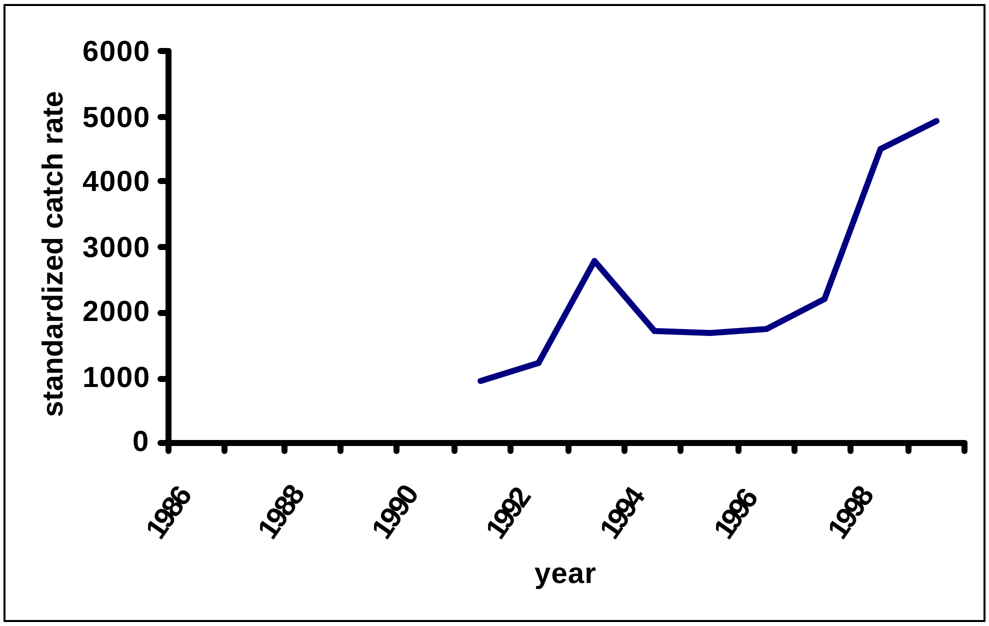



Figure 15. Standardized catch rates in pounds landed per day from longline effort in reef fish log book reports.

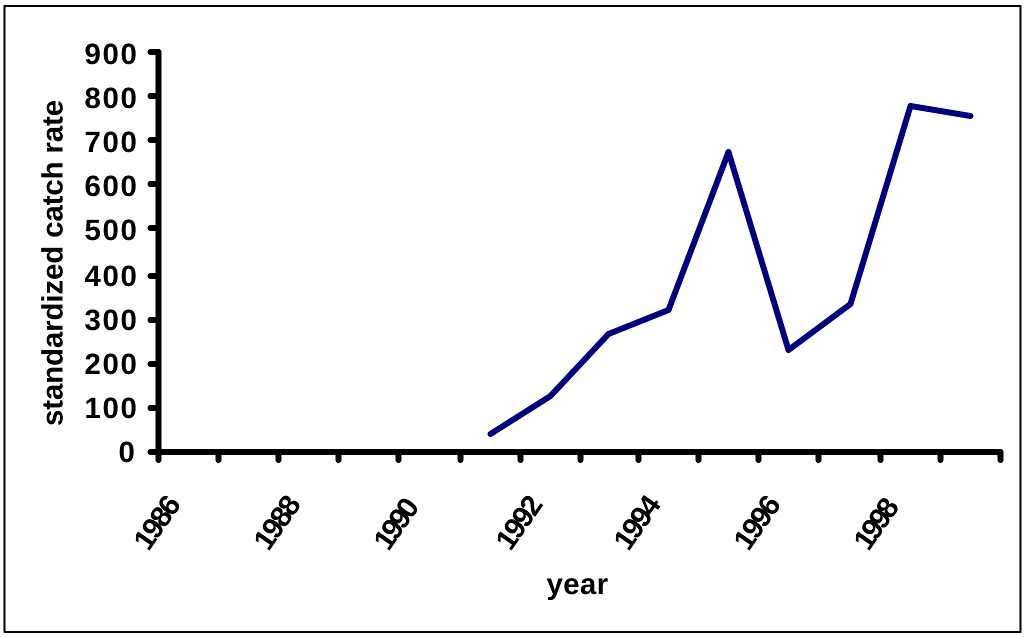



Figure 16. Standardized catch rates in pounds landed per day from trap effort in reef fish log book reports using a model without year interactions.

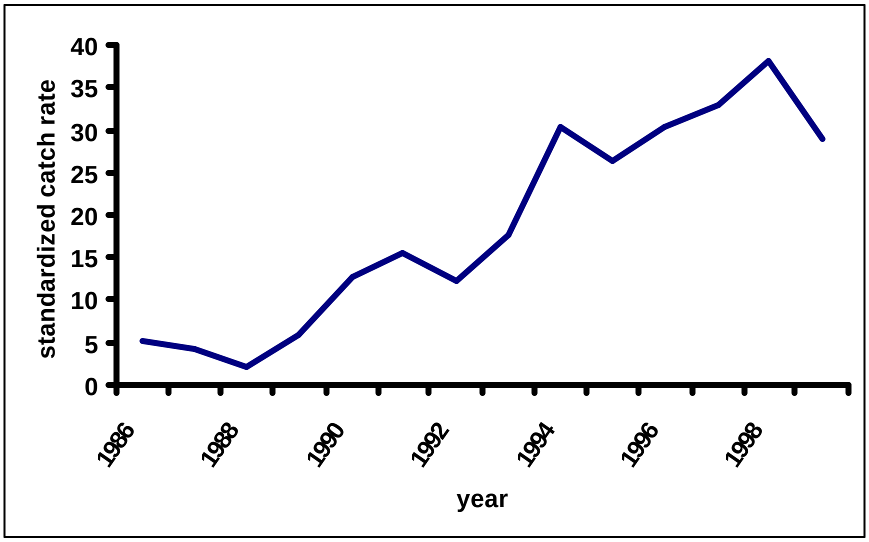



Figure 17. Standardized catch rates in fish per 1000 angler hours from MRFSS dock-side sampling including both landed and discarded (dead and alive) catches.

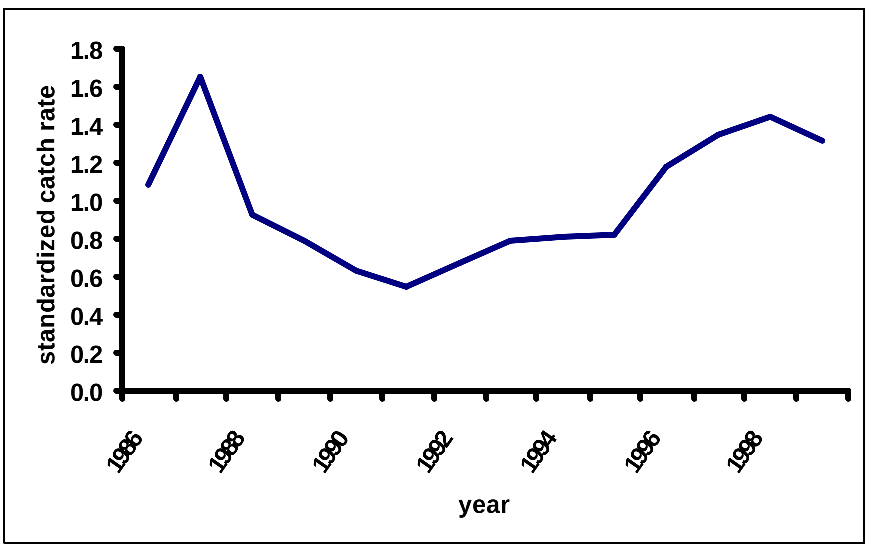



Figure 18. Standardized catch rates from headboat landings.

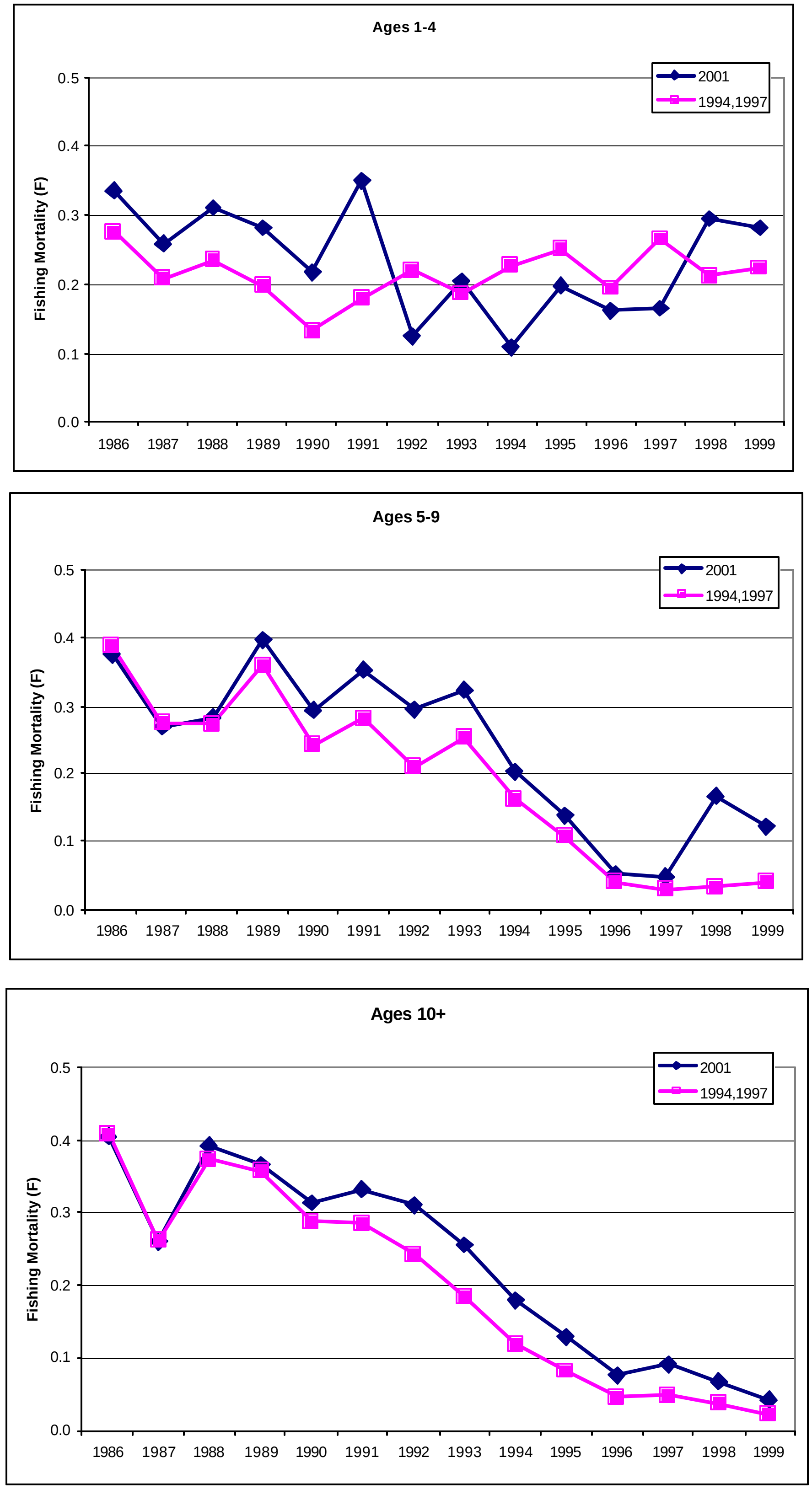



Figure 19. Comparison of the effect of different growth equations on fishing mortality rates by age.

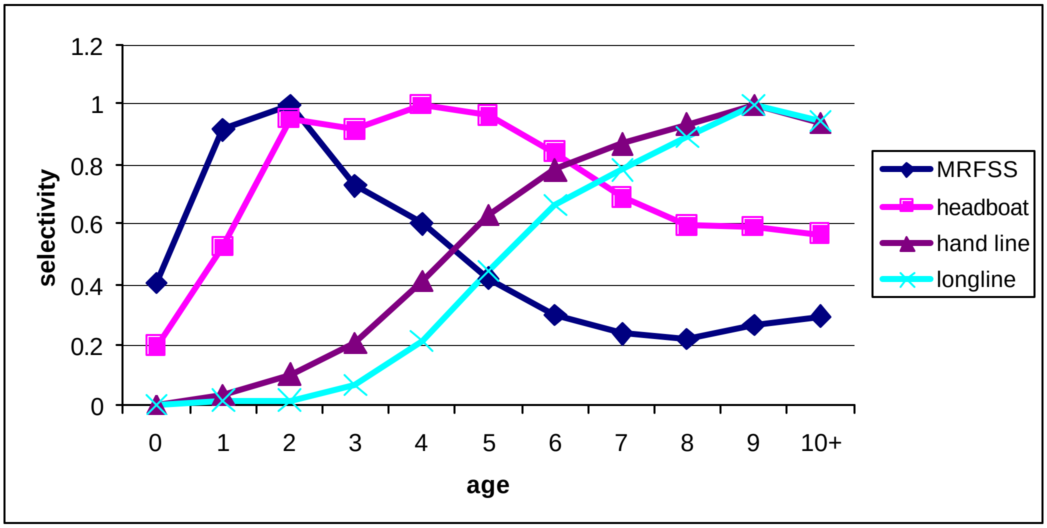



Figure 20. Selectivities of the fisheries with indices of abundance, assumed constant over the period of covered by the index.

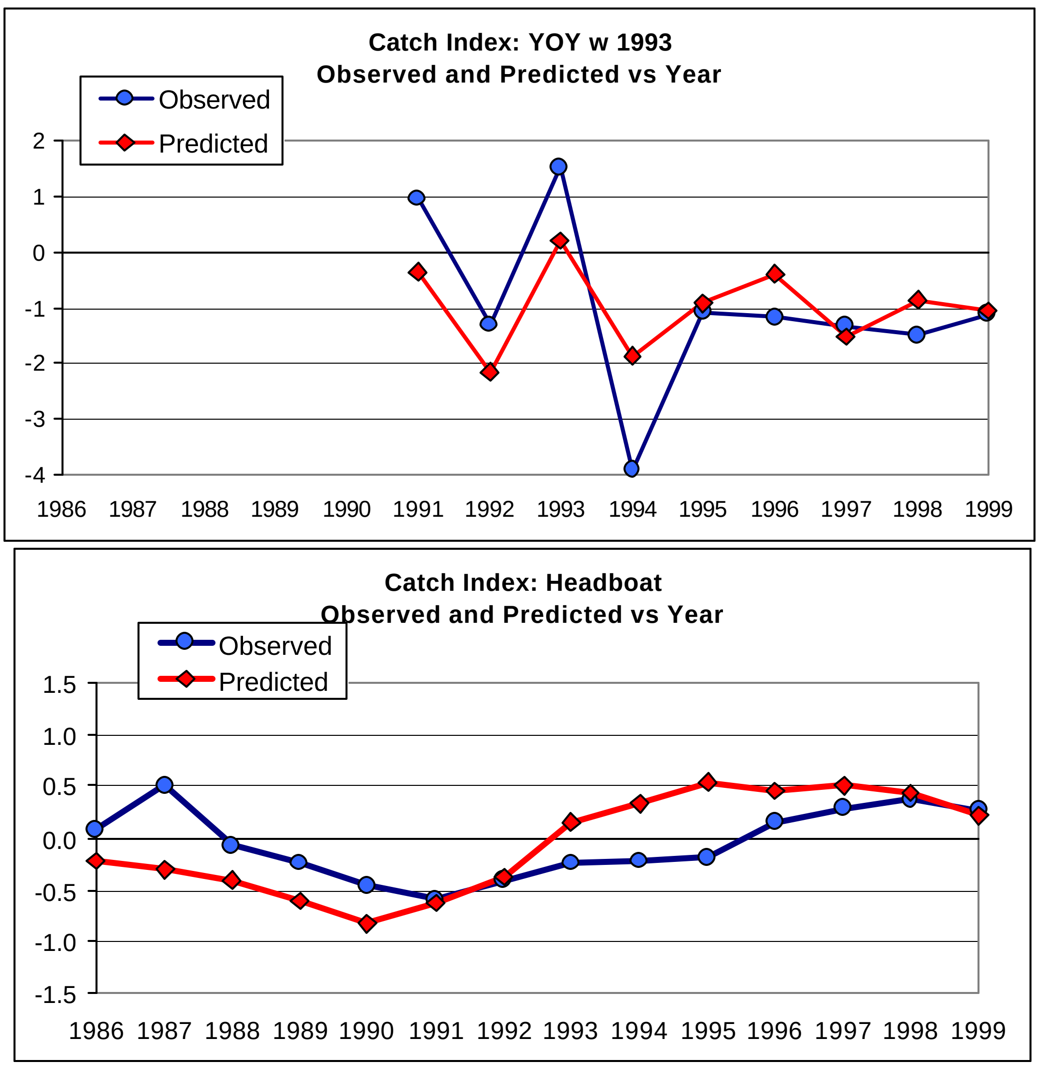



Figure 21. Fits to indicies in VPA analysis of the RMM catch-at-age with year-constant selectivity (continued on next page).

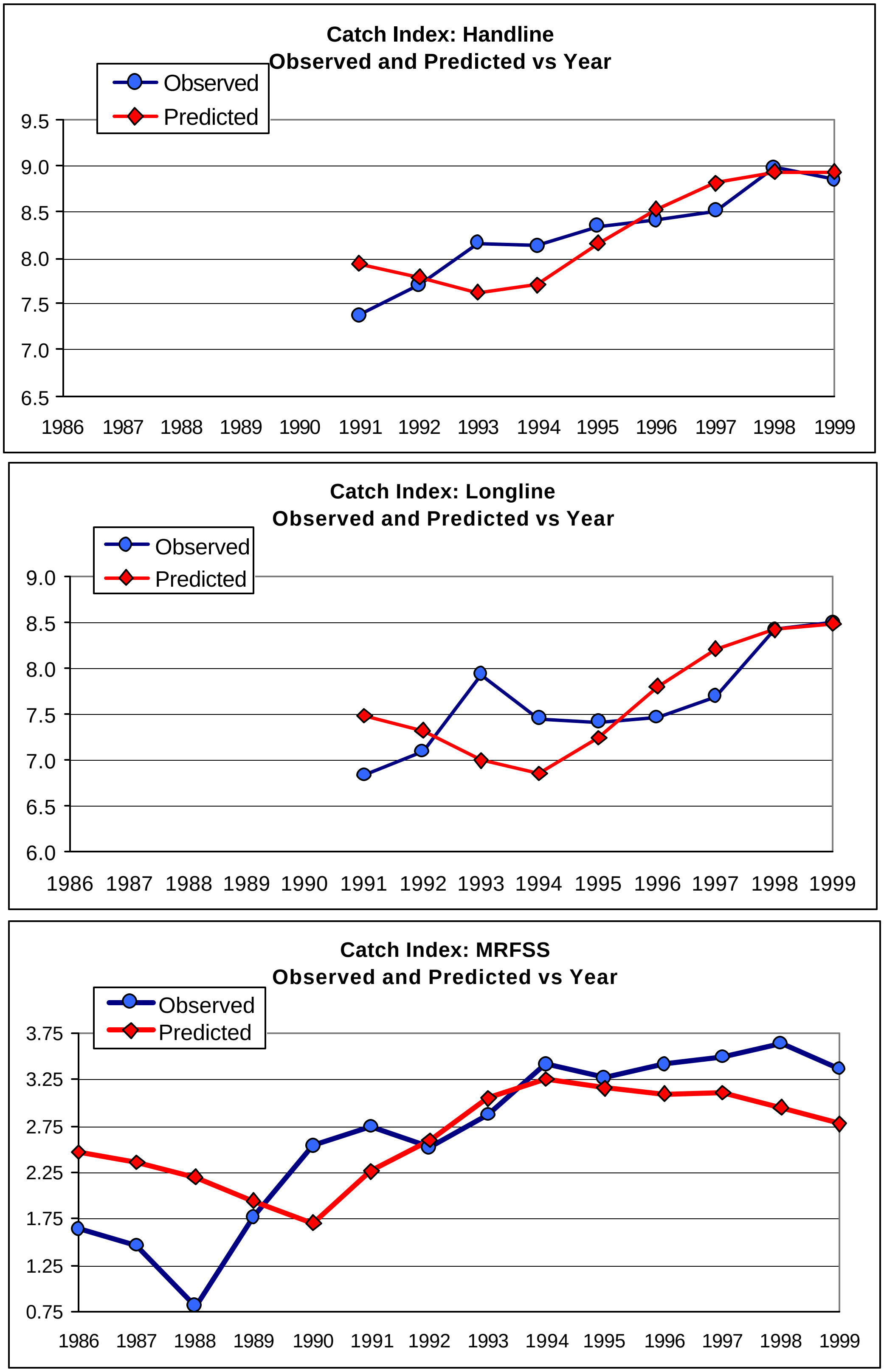
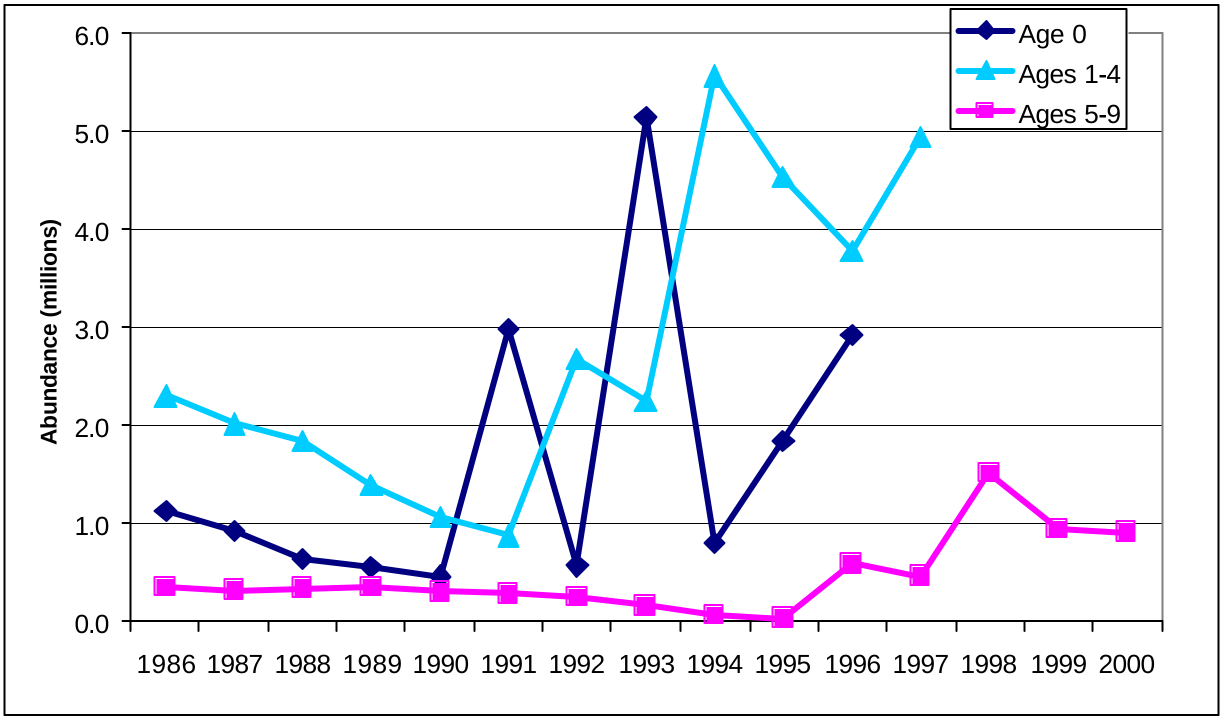



Figure 21, continued. Fits to indices from VPA on RMM catch-at-age with year-constant selectivity.



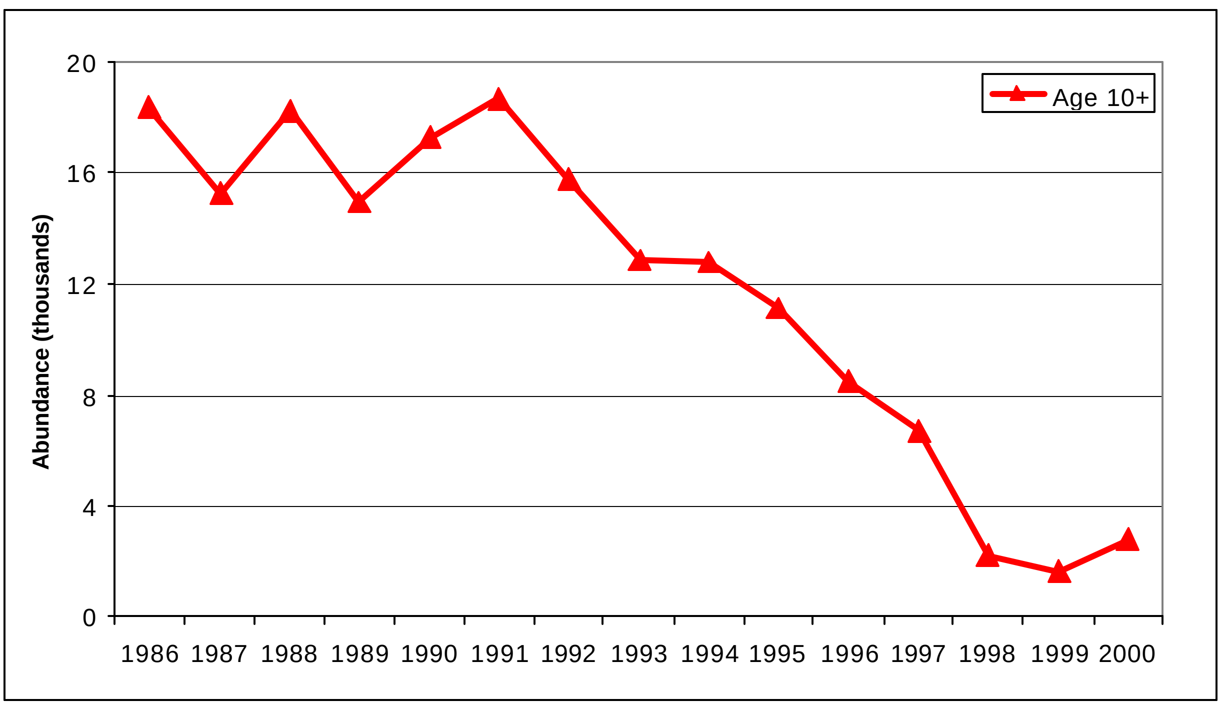




Figure 22. Estimated abundances from the VPA on the RMM catch-at-age with year-constant selectivity .

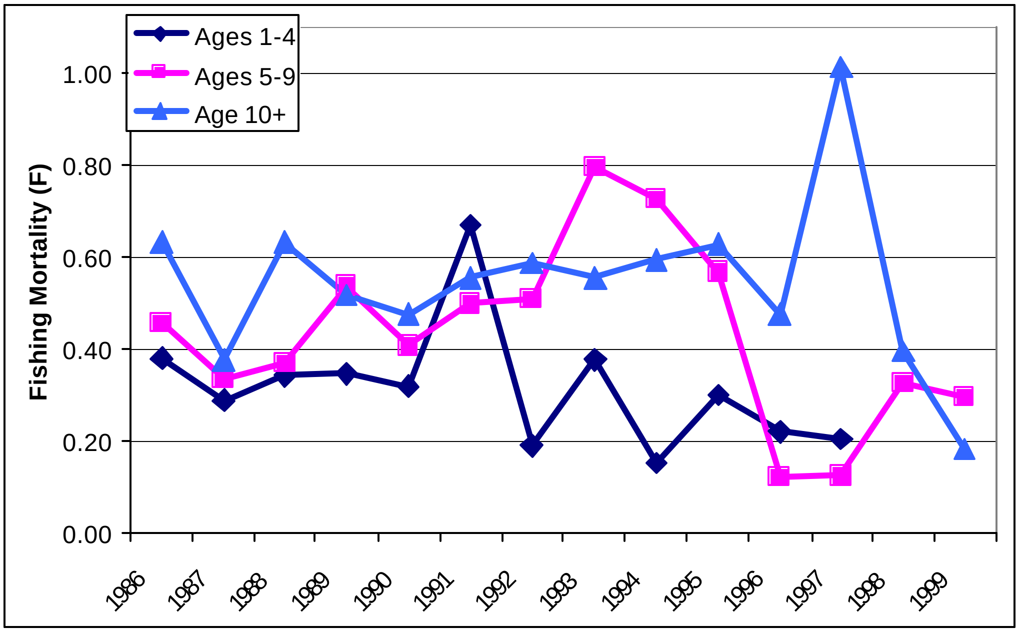
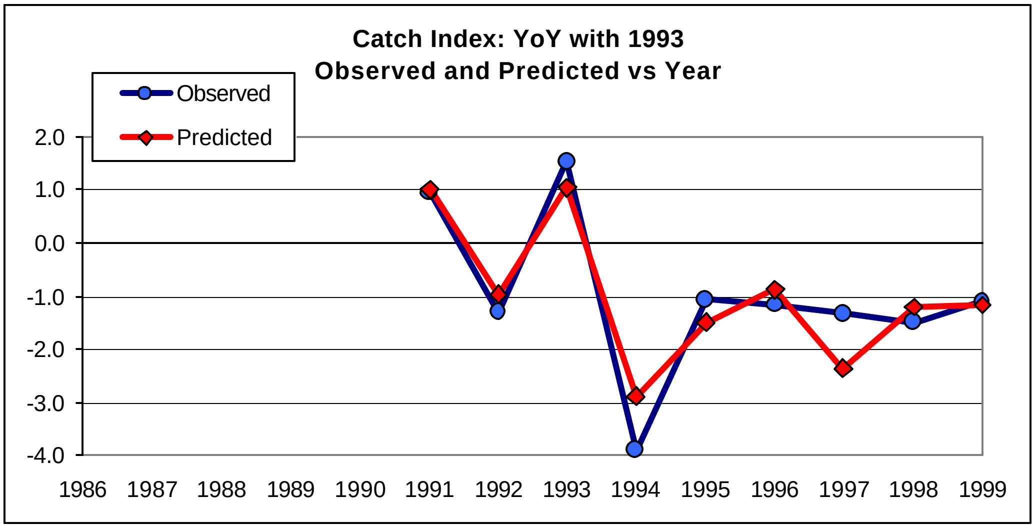
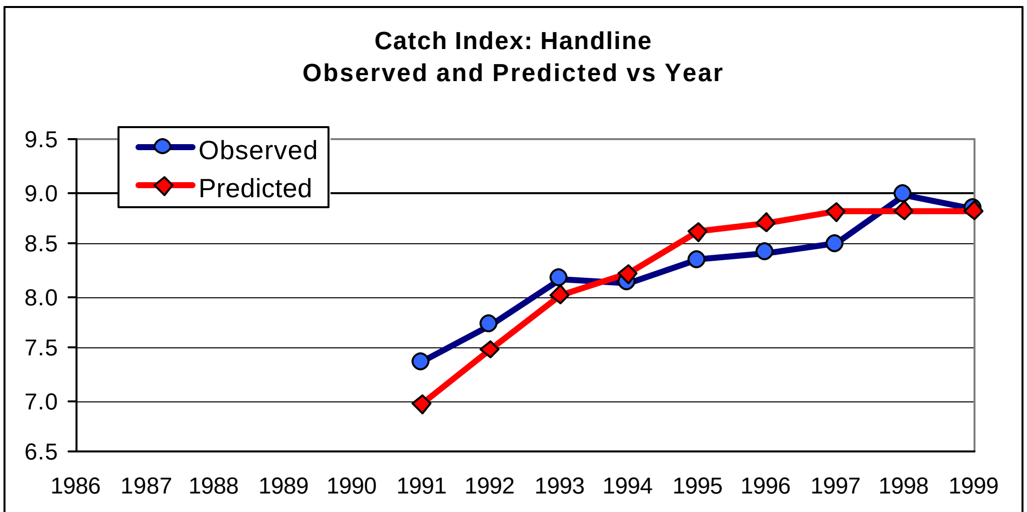


Figure 23. Estimated fishing mortality rate from the VPA. On the RMM catch-at-age with year-constant selectivity.



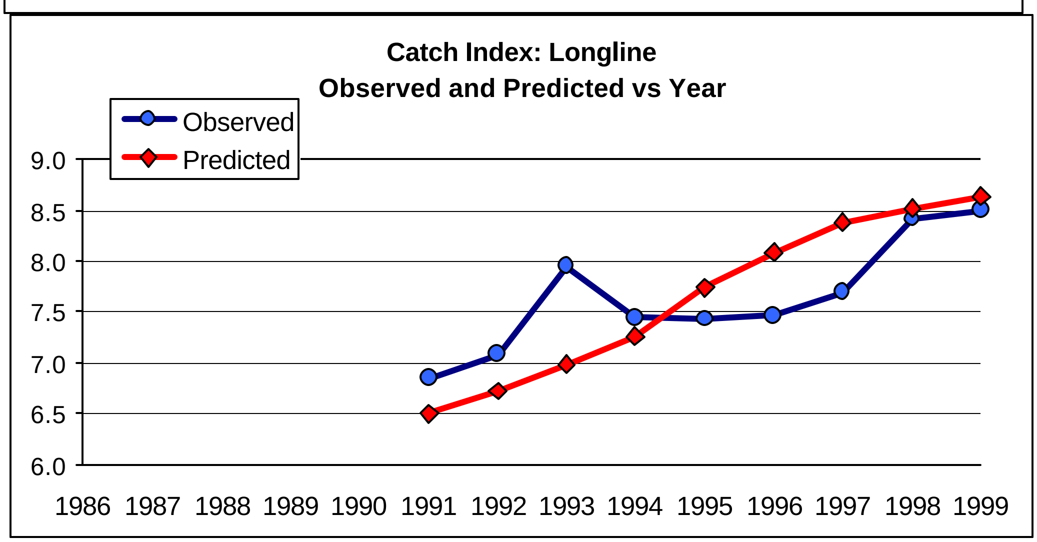




Figure 24. Fits to indices from the sensitivity analysis with the commercial indices and the young of the year index.

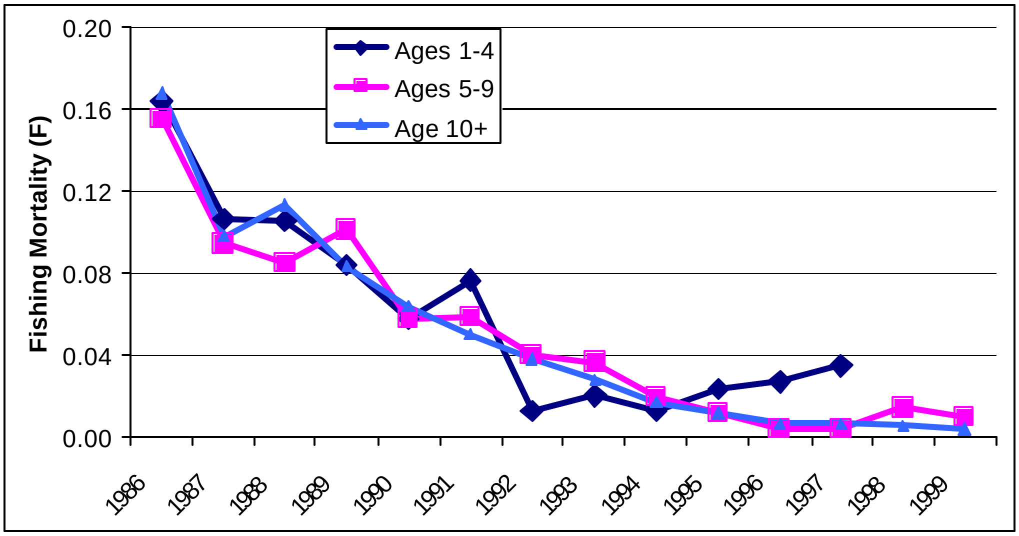
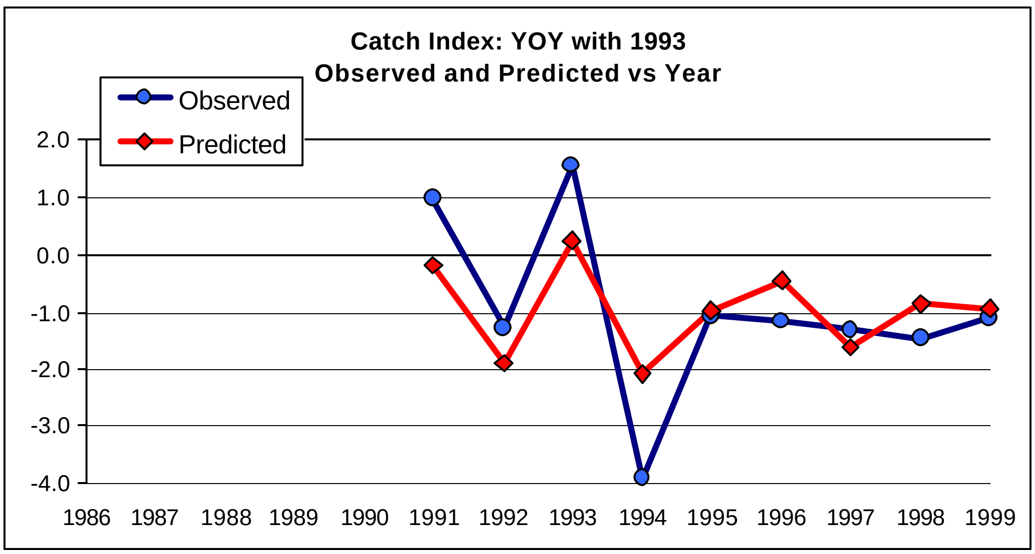



Figure 25. Fishing mortality rates from the sensitivity analysis using the commercial indices and the young of the year index.



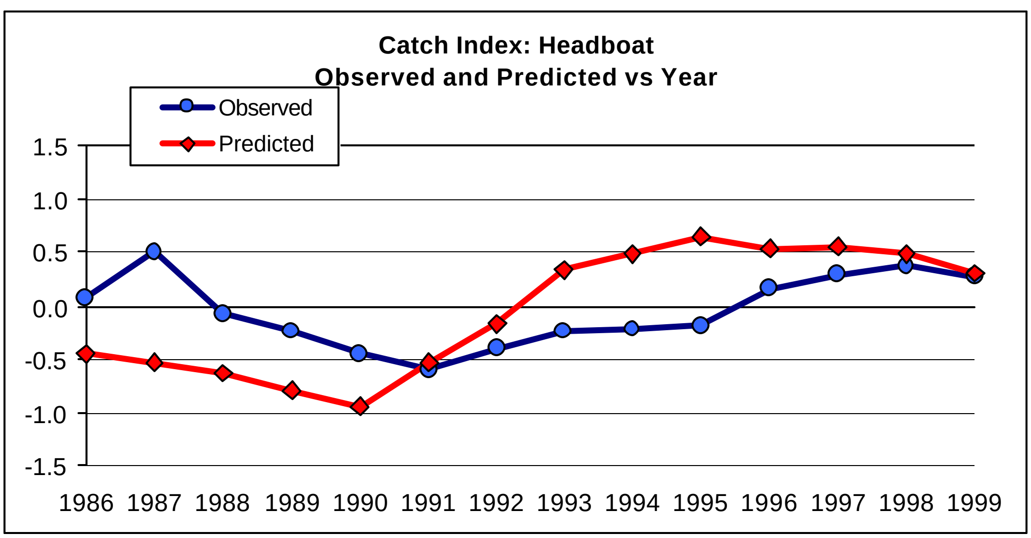




Figure 26. Fits to the indices from sensitivity analysis using recreational indices and the young of the year index (continued on next page).

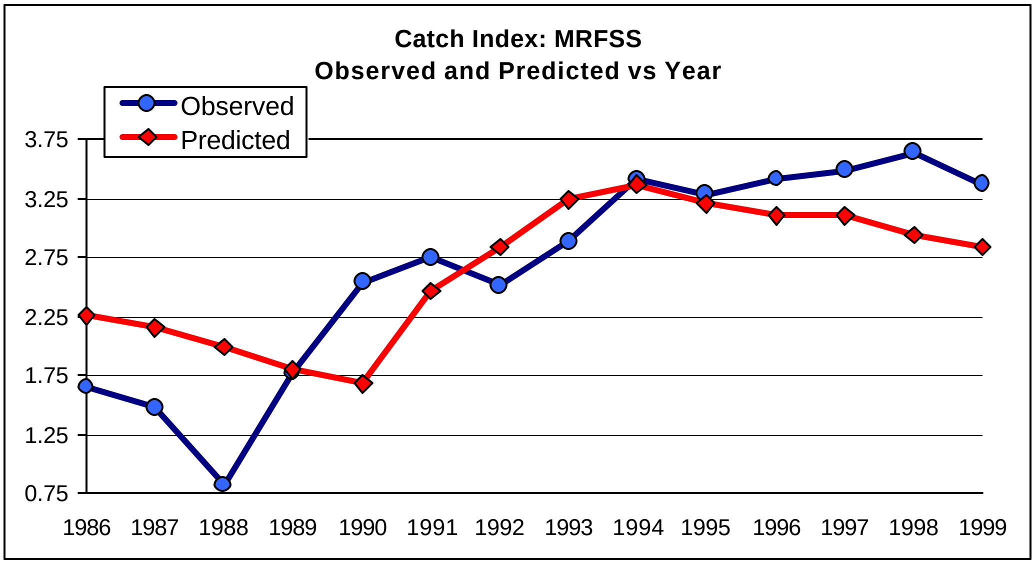



Figure 26 continued.

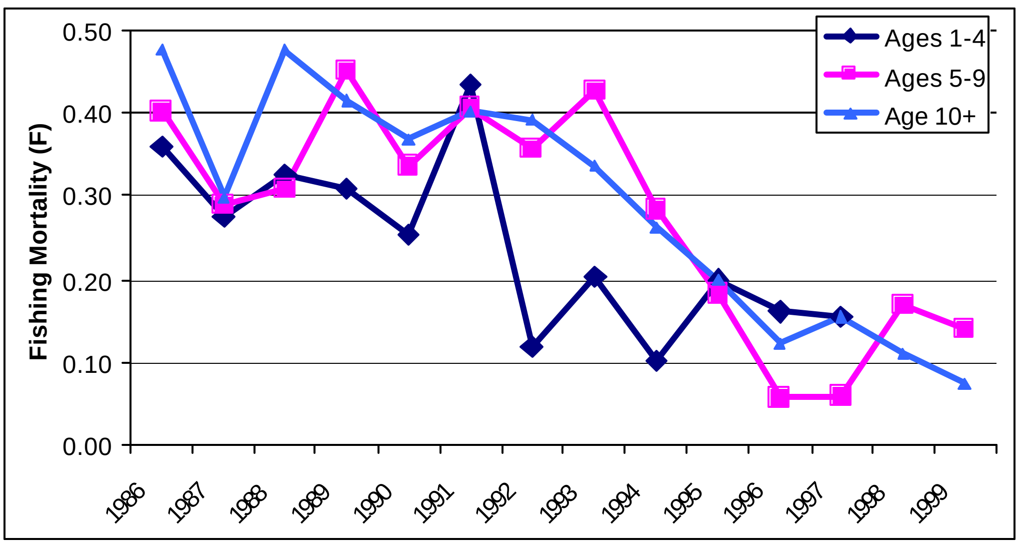



Figure 27. Fishing mortality rates estimated from analysis of recreational indices and the young of the year index.

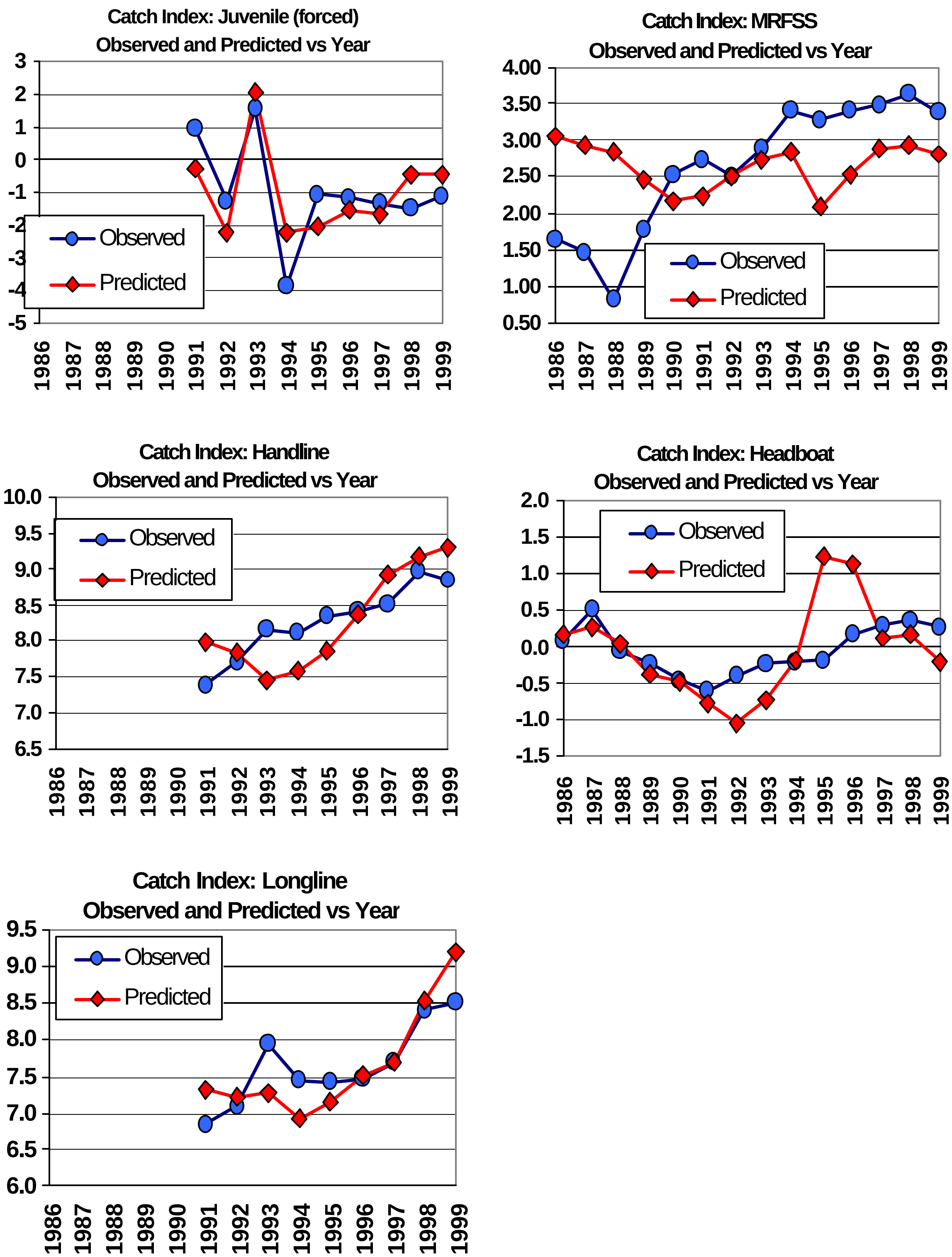



Figure 28. Index fits from the VPA using the recruitment-and-mortality modulated catch-at-age with year variable index selectivity.

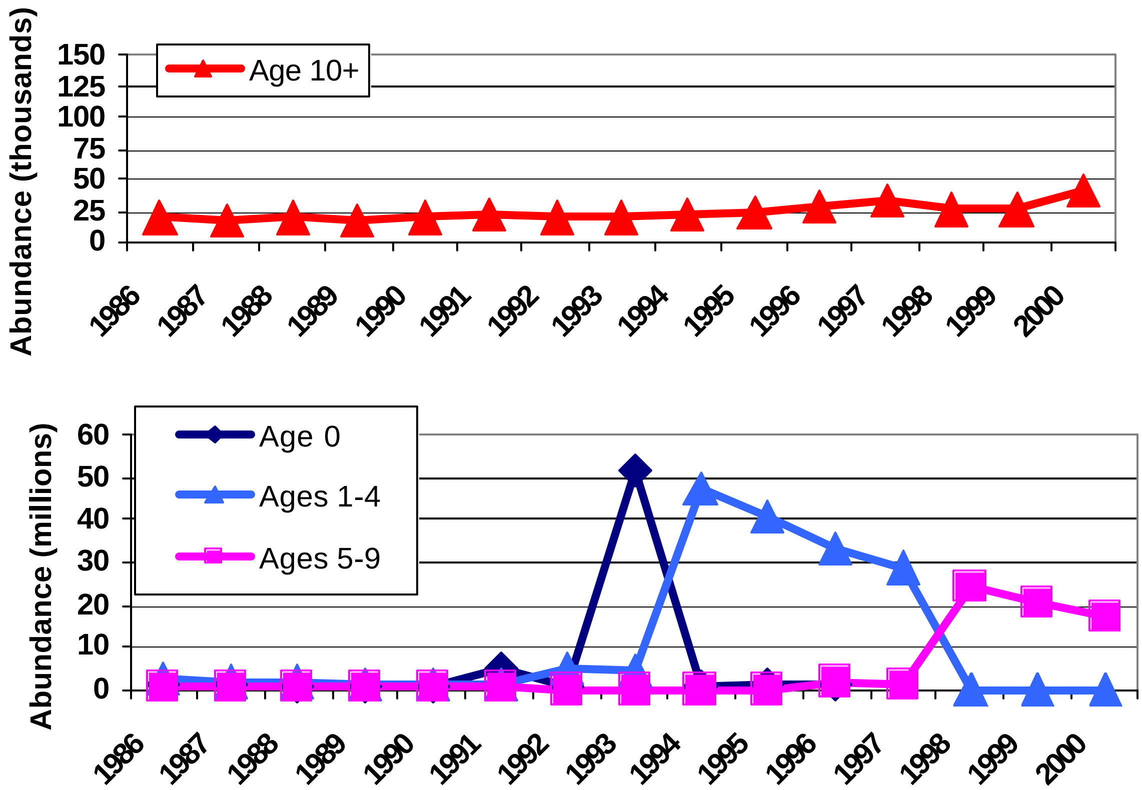



Figure 29. Estimated abundances from the VPA using the recruitment-and-mortality modulated catch-at-age and year variable index selectivity.

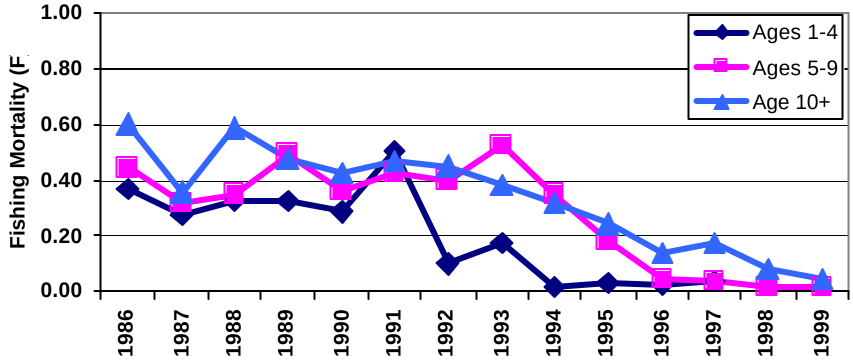



Figure 30. Estimated fishing mortality from the VPA which used the recruitment-and-mortality modulated catch-at-age with assumed year variable selectivity.

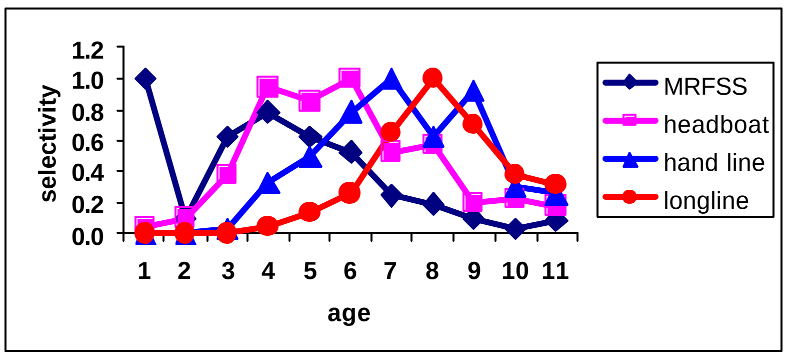



Figure 31. Index selectivity from the VPA which used the age-length-key plus stochastic growht catch-at-age and the assumed year constant selectivity.

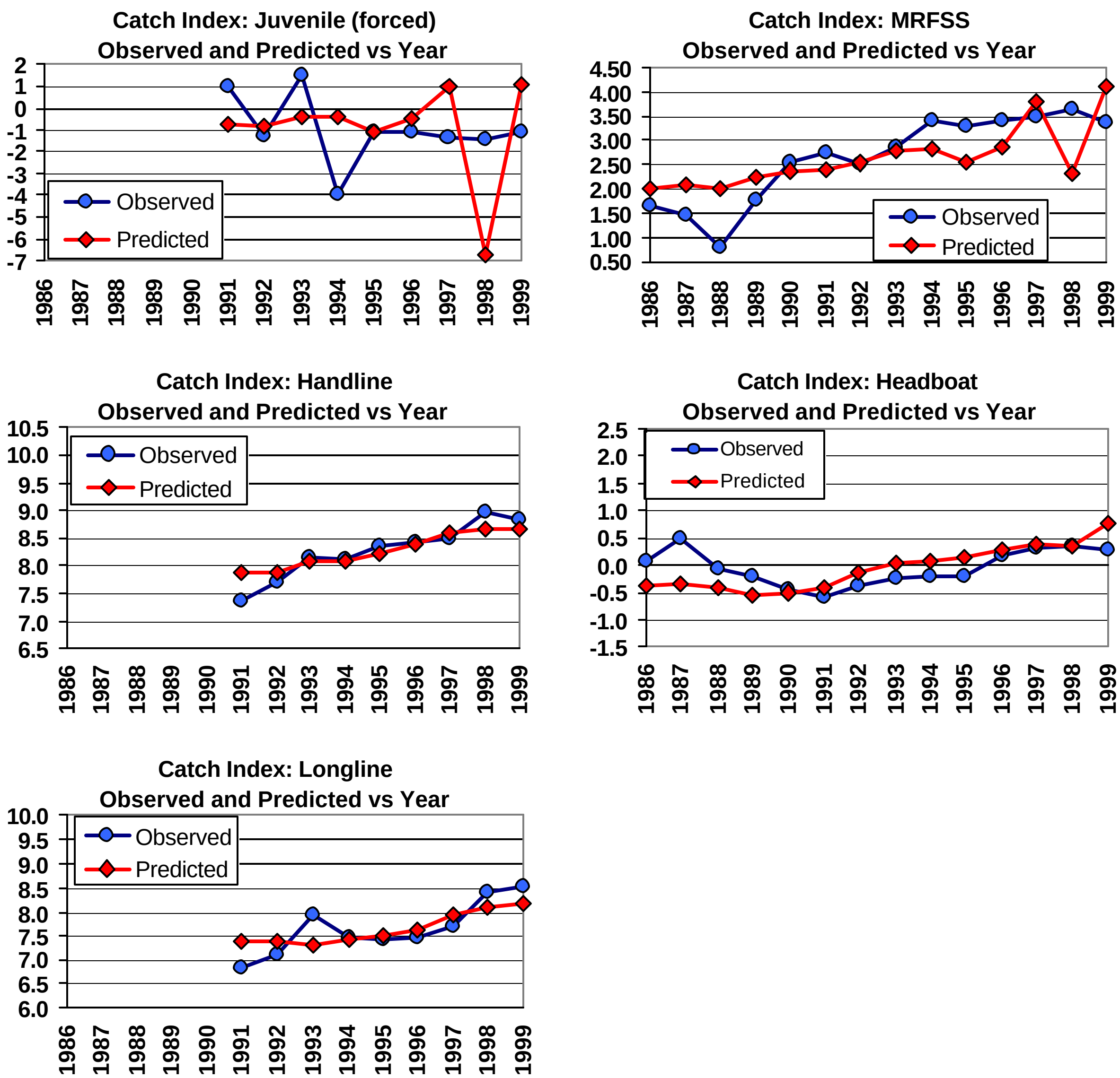



Figure 32. Index fits from the VPA which used the age-length-key plus stochastic growth catch-at-age with the assumed year constant index selectivity.

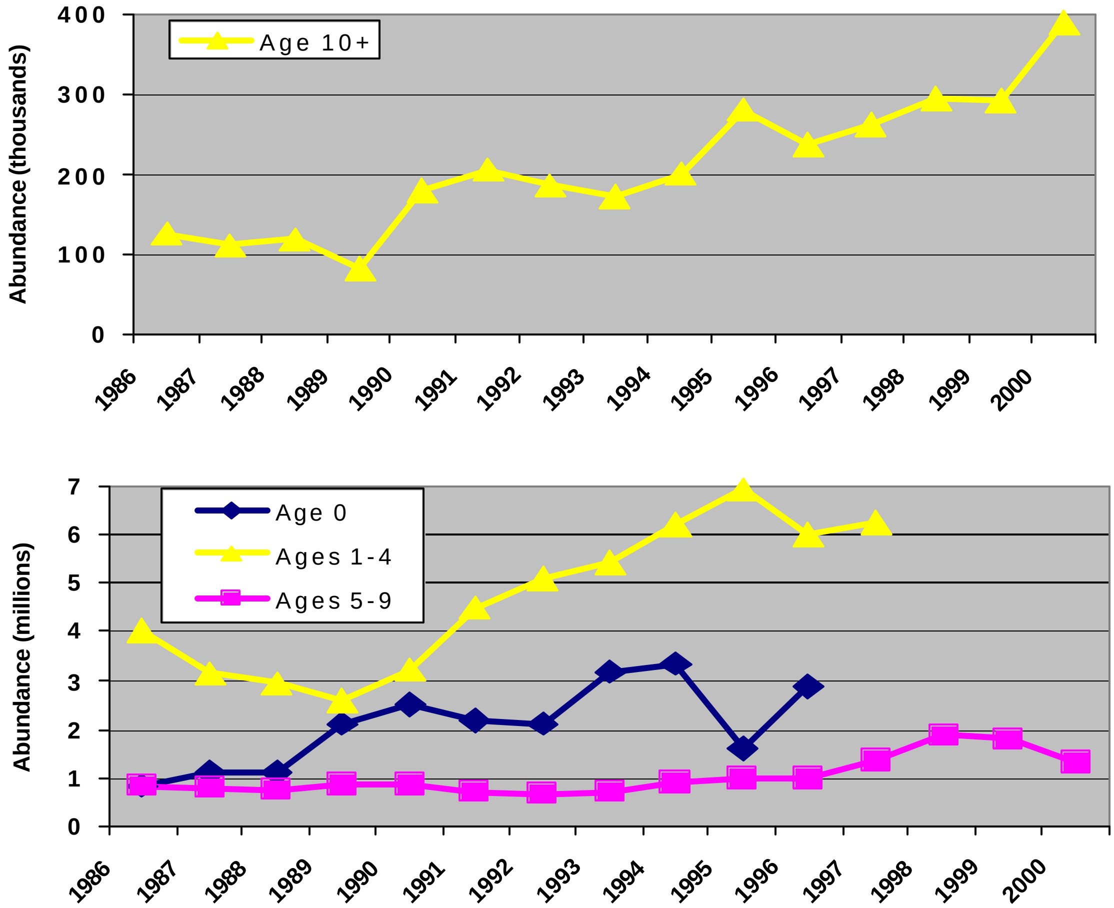



Figure 33. Estimated abundances from the VPA of the age-length-key with stochastic ageing catch-at-age with assumed year constant index selectivity.

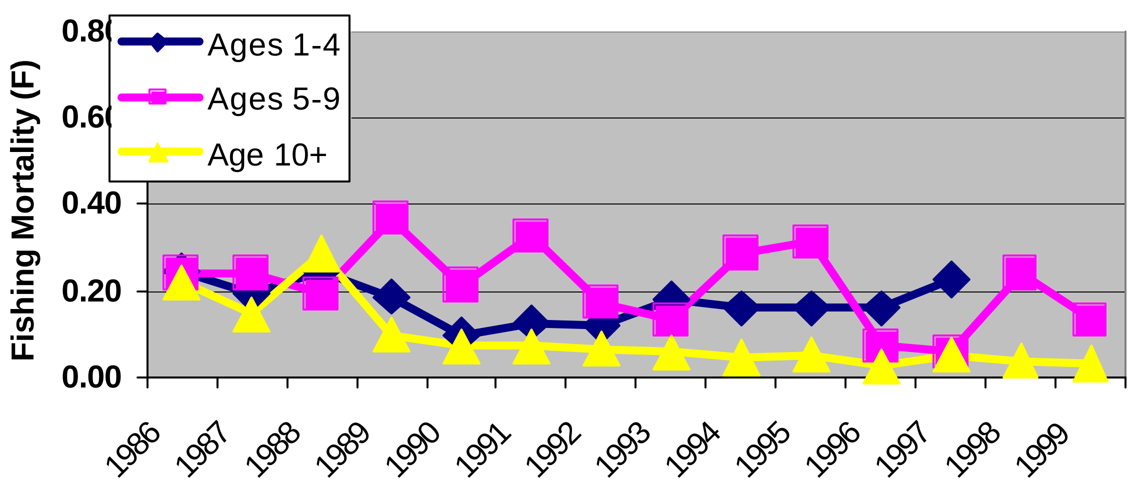



Figure 34. Estimated fishing mortality rates from the VPA which used the age-length-key plus stochastic ageing catch-at-age with assumed constant index selectivity.

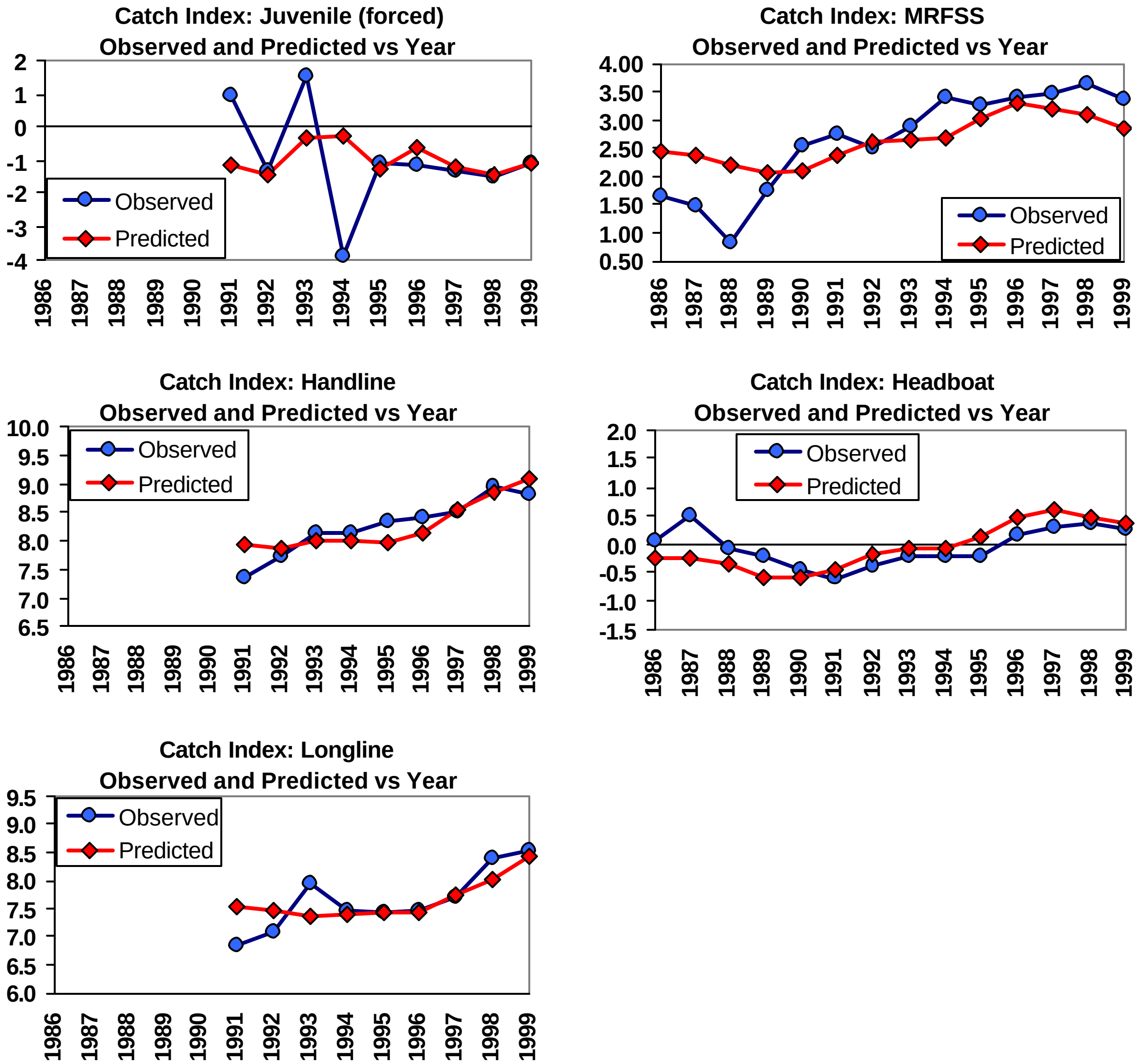



Figure 35. Index fits from the sensitivity VPA which used the age-length-key plus stochastic growth catch-at-age with the assumption of year constant index selectivity and in which fishing mortality rates in 1999 for ages 0, 1, 2, 4, and 6 years were estimated.

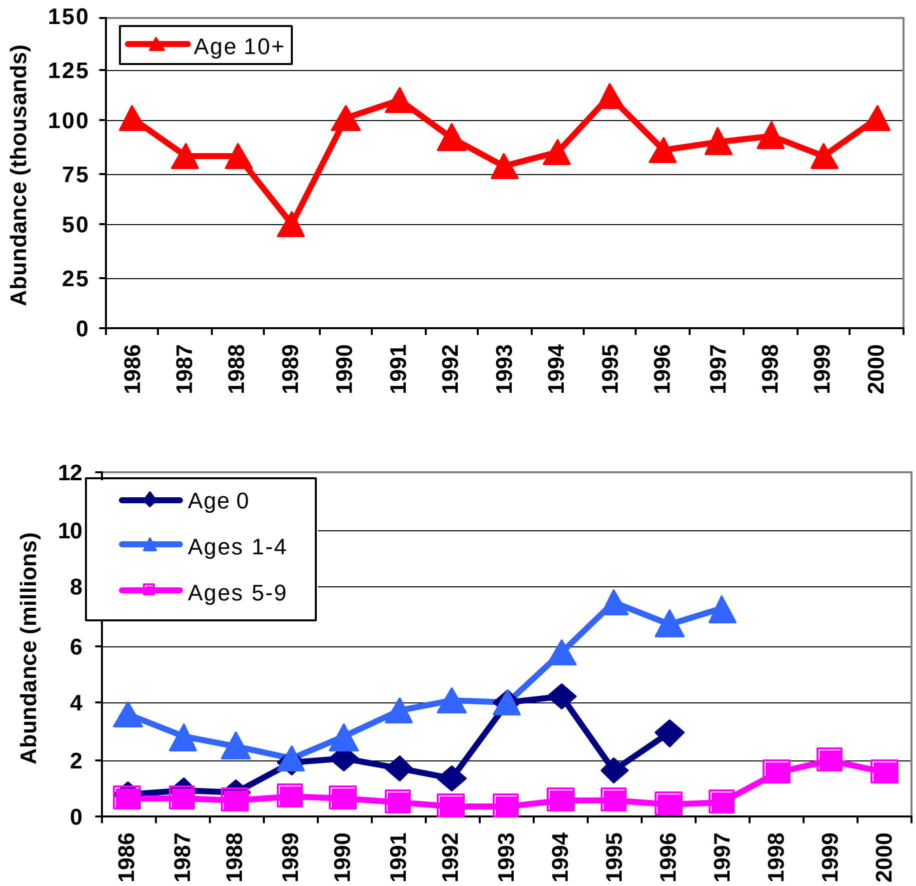



Figure 36. Estimated abundance from the sensitivity VPA which used the age-length-key plus stochastic growth catch-at-age with the assumption of year constant index selectivity and in which fishing mortality rates in 1999 for ages 0, 1, 2, 4, and 6 years were estimated.

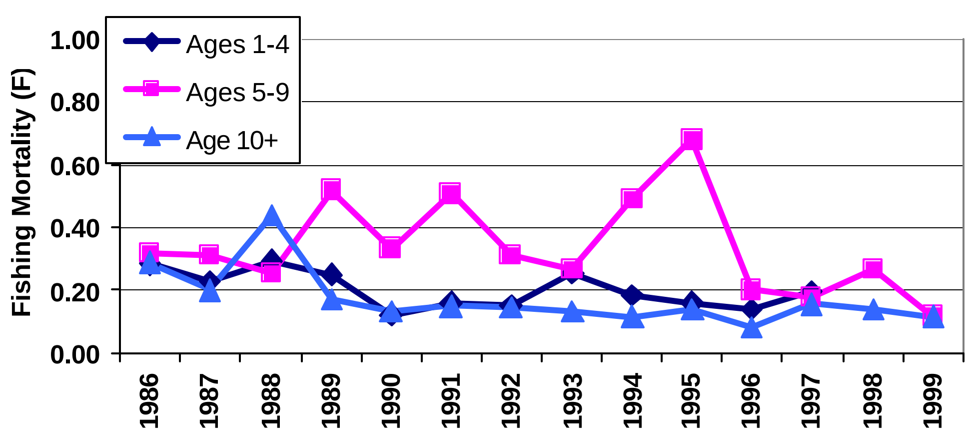



Figure 37. Estimated fishing mortality rates from the sensitivity VPA which used the age-length-key plus stochastic growth catch-at-age with the assumption of year constant index selectivity and in which fishing mortality rates in 1999 for ages 0, 1, 2, 4, and 6 years were estimated.

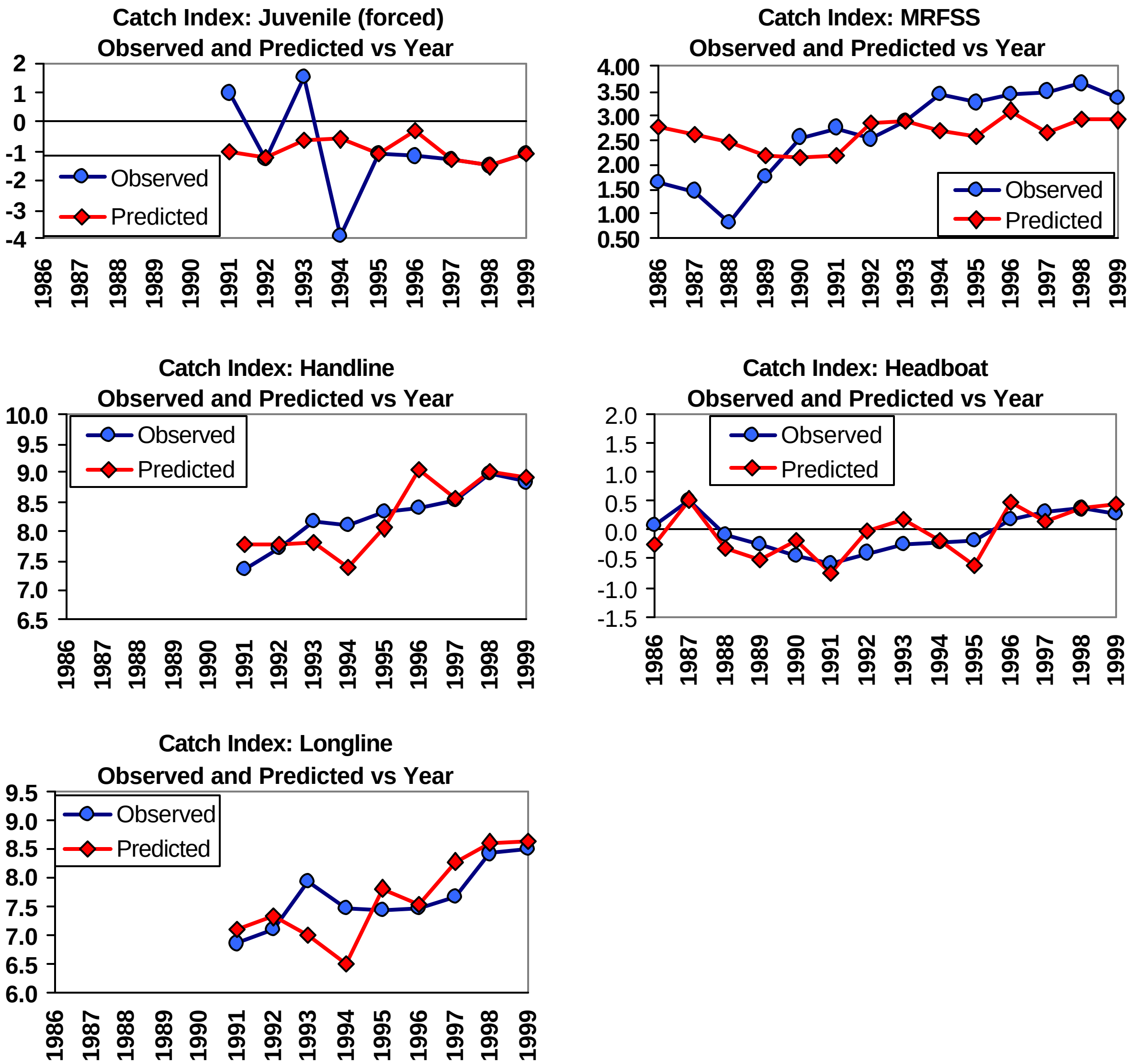



Figure 38. Index fits from the VPA which used the age-length-key plus stochastic growth catch-at-age with the assumption of year variable index selectivity.

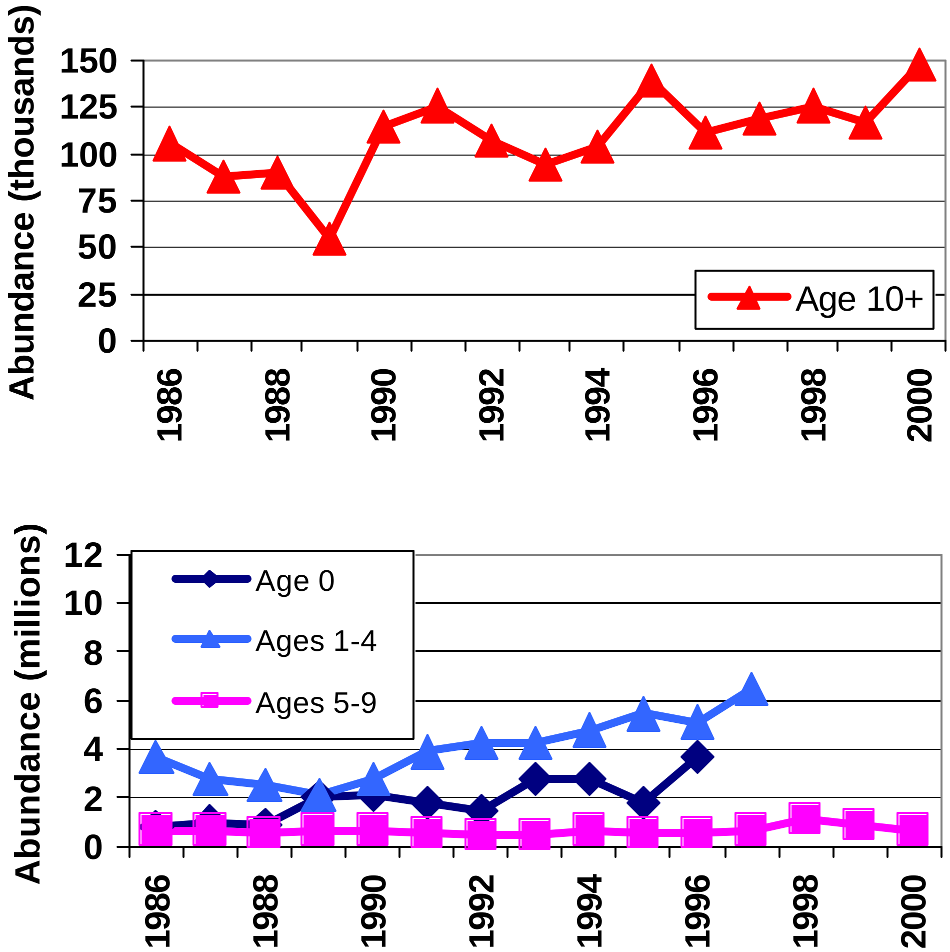



Figure 39. Estimated abundances from the VPA which used the age-length-key plus stochastic growth catch-at-age with the assumption of year variable index selectivity.

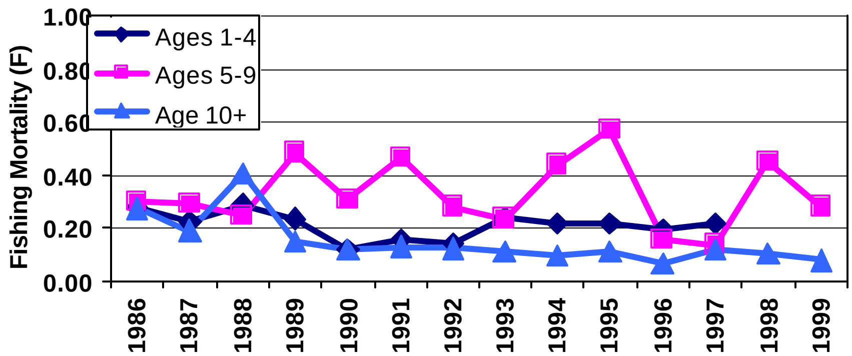



Figure 40. Estimated fishing mortality rates from the VPA which used the age-length-key plus stochastic growth catch-at-age with the assumption of year variable index selectivity.

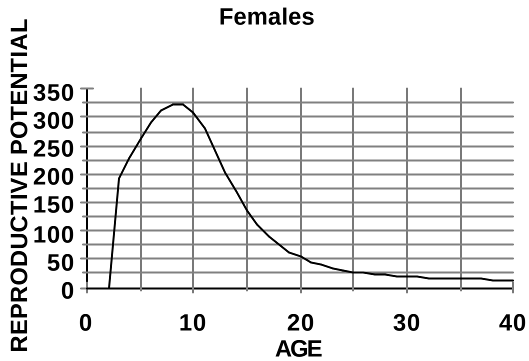



Figure 41. Female reproductive potential used in calculating spawning stock biomass. Units are grams of mature ovaries.


Figure 42. Male reproductive potential used in calculating male spawning stock biomass. Units are pounds of mature males.

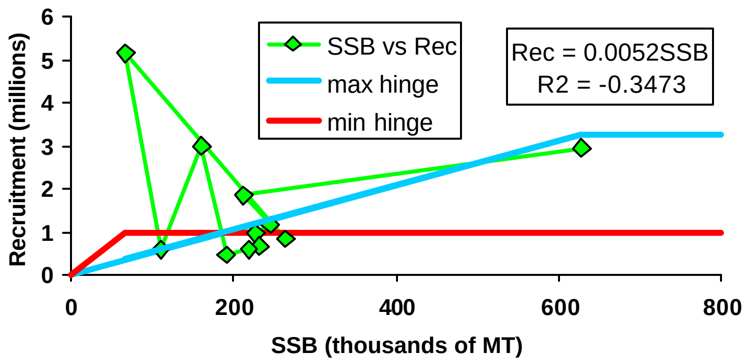



Figure 43. Spawning stock size, recruitment and stock recruitment functions from the VPA which used the recruitment-and-mortality modulated catch-at-age and assumed year constant index selectivity.

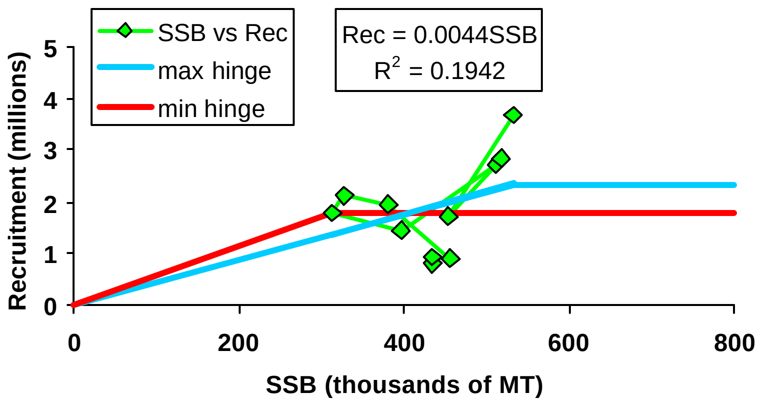



Figure 44. Spawning stock size, recruitment, and stock-recruitment functions from the VPA which used the age-length-key plus stochastic growth catch-at-age with assumed year variable index selctivity.

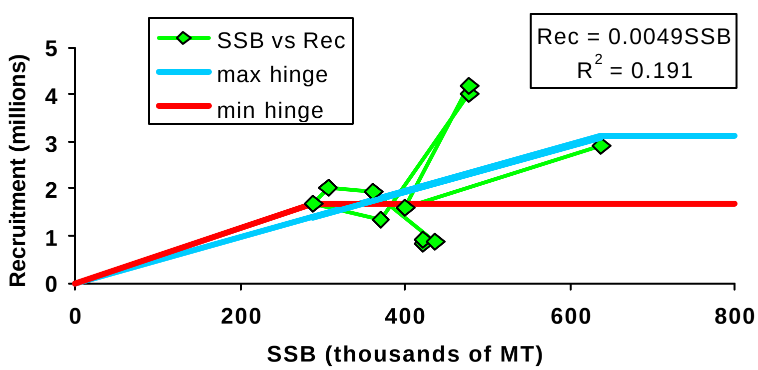



Figure 45. Spawning stock size, recruitment, and stock-recruitment functions from the sensitivity VPA which used the age-length-key plus stochastic growth catch-at-age with assumed year constant index selectivity and in which 1999 fishing mortality was estimates for ages 0, 1, 2, 4 and 6 years.

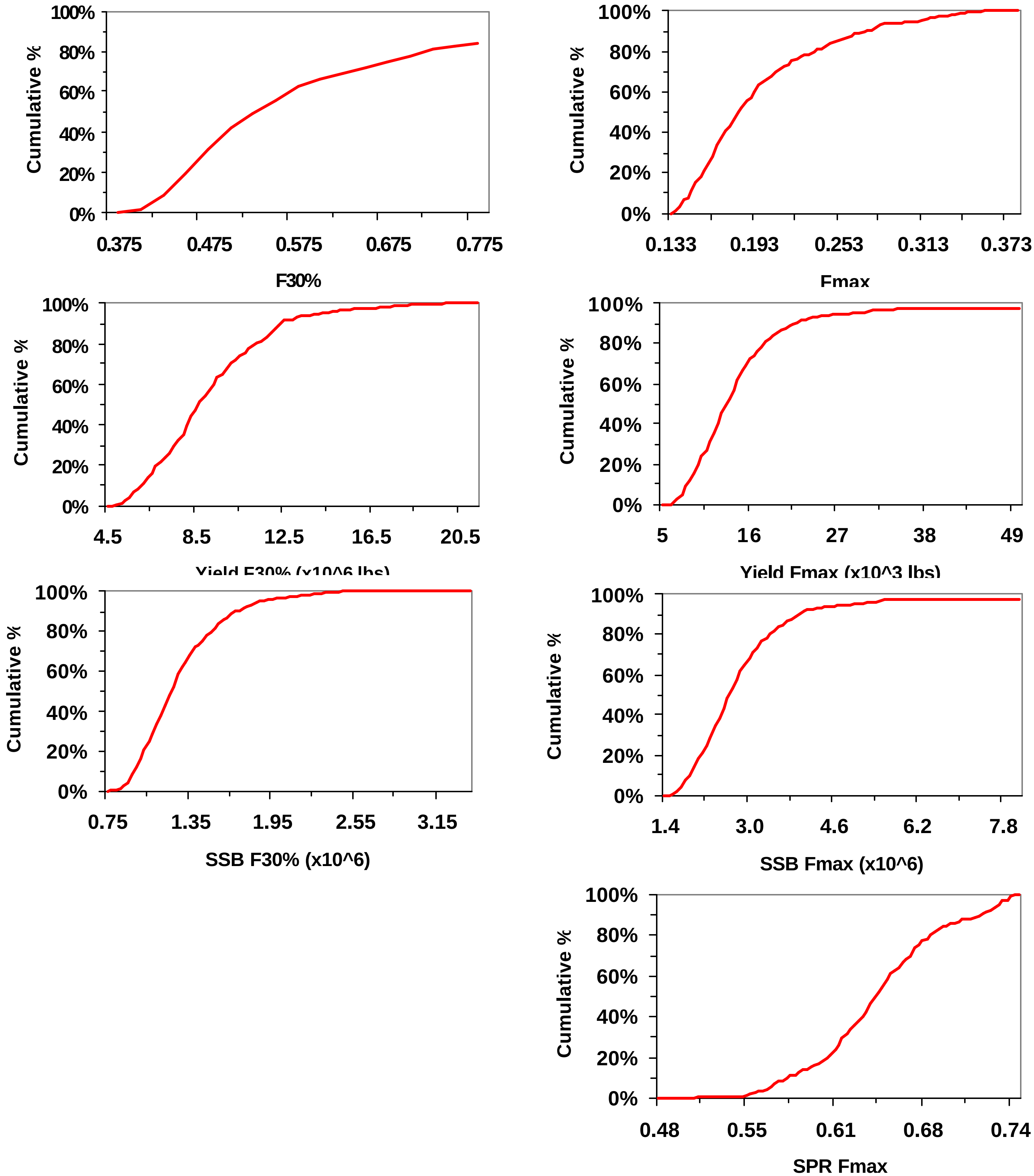



Figure 46. Cumulative frequency distributions for various reference statistics from bootstrapped estimates from the sensitivity VPA using the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size.

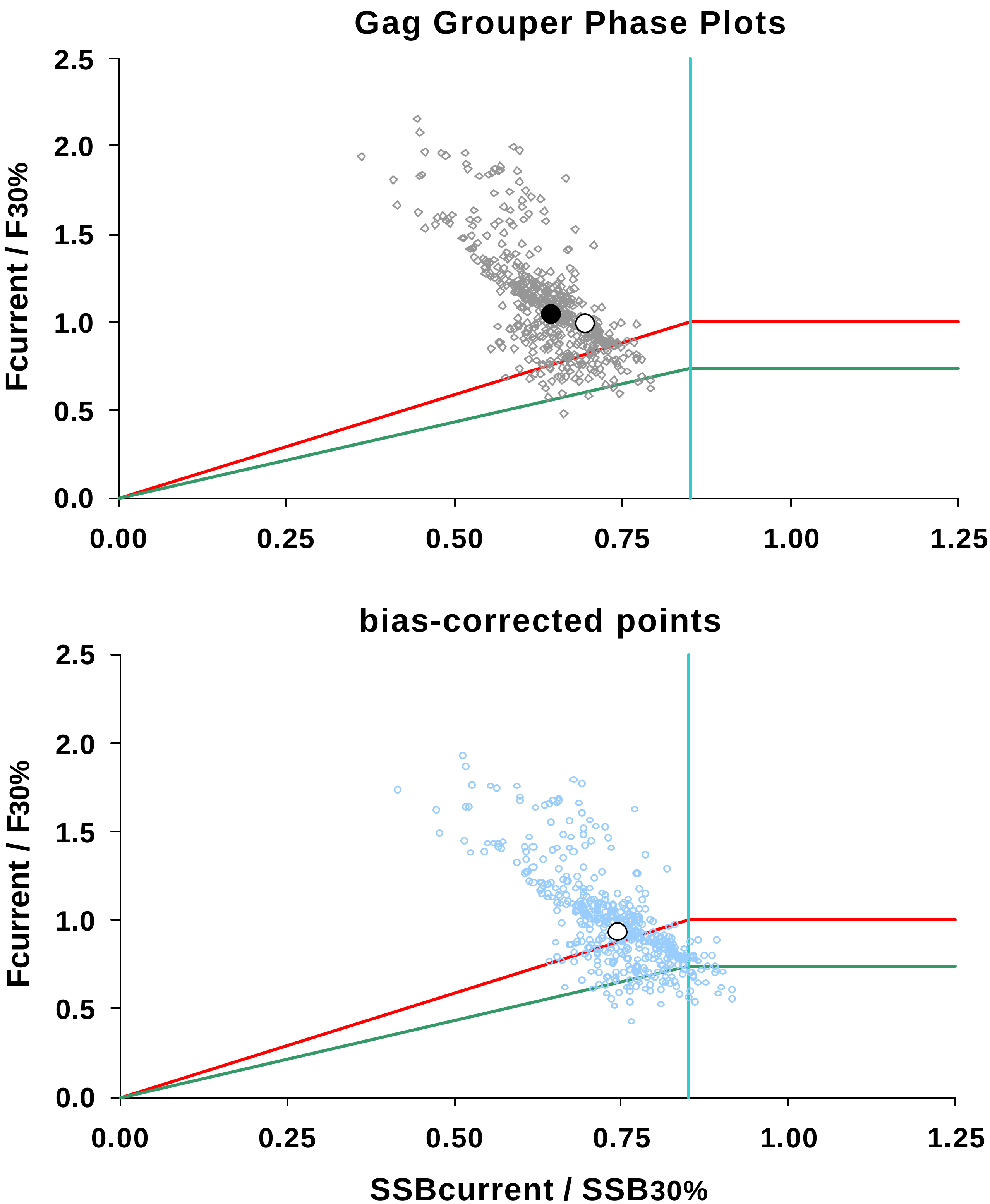



Figure 47. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to $SSB_{30\%}$ and $F_{30\%}$, respectively, from the analysis of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and the deterministic estimates.

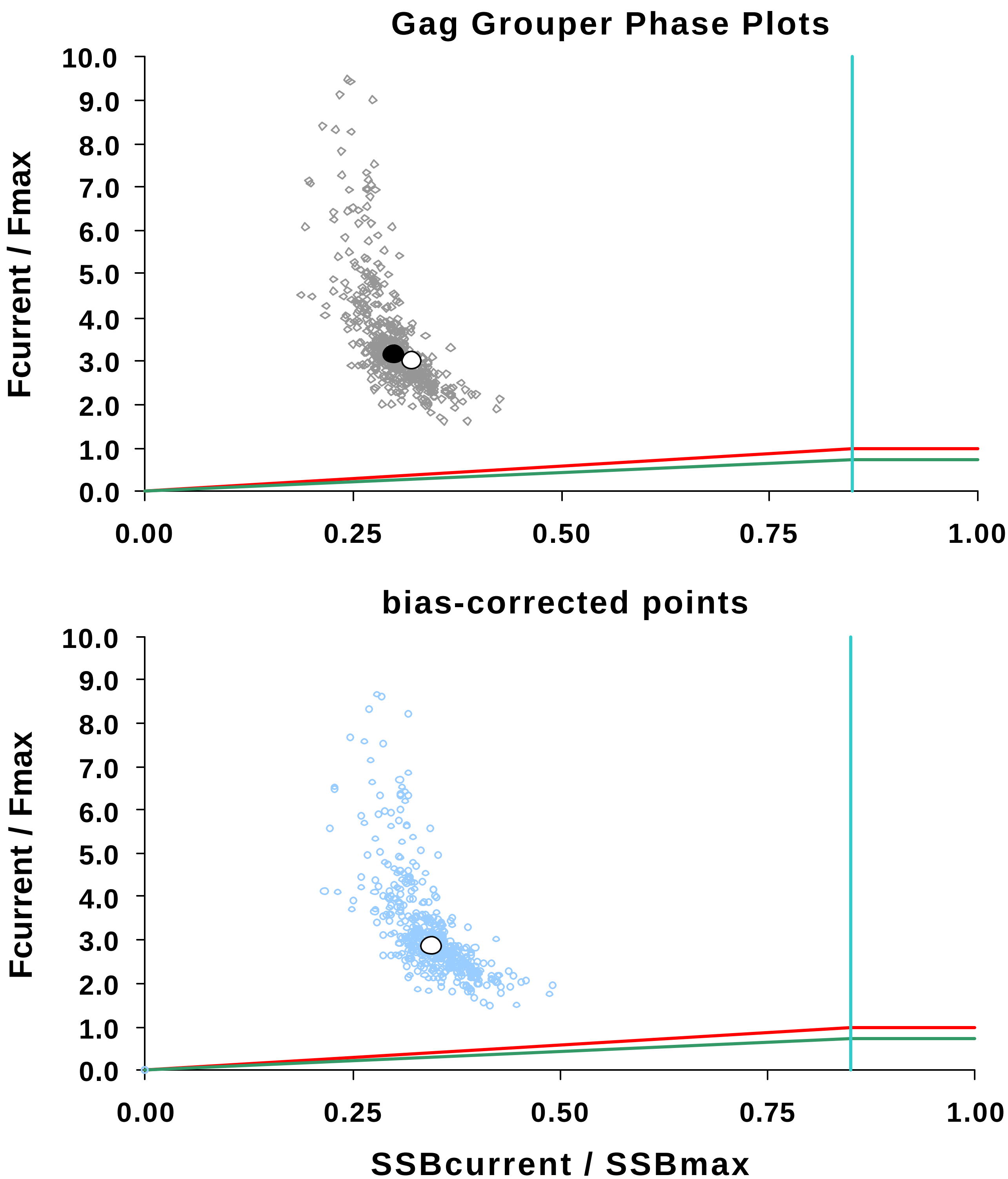



Figure 48. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to SSB and F at $F_{max}$ from the analysis of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and the deterministic estimates.

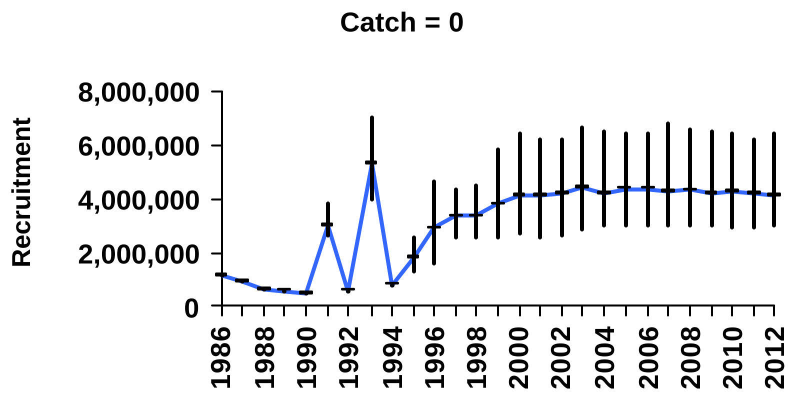



Figure 49. Historical and projected recruitment (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch after 2001.

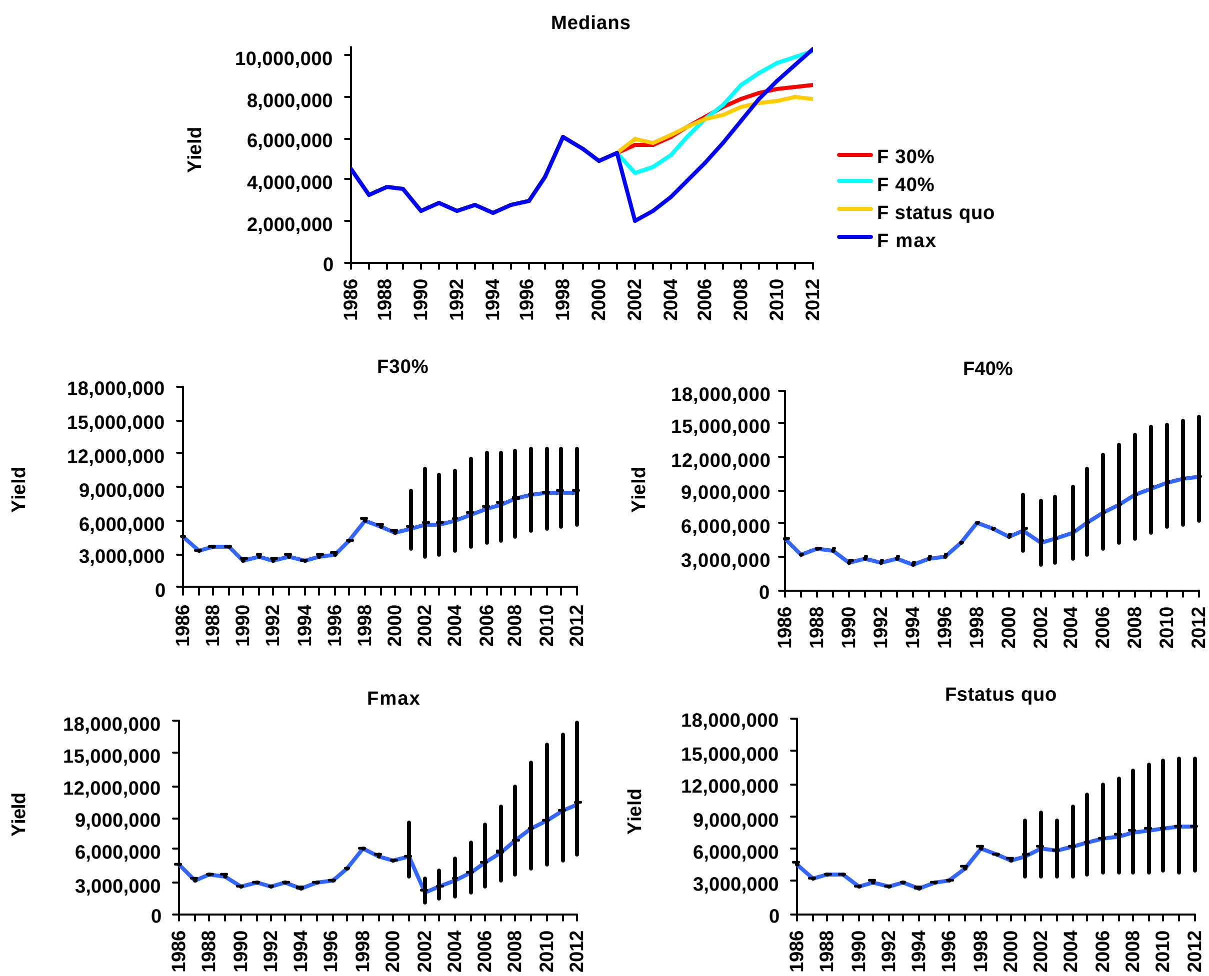



Figure 50. Historical and projected yield (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

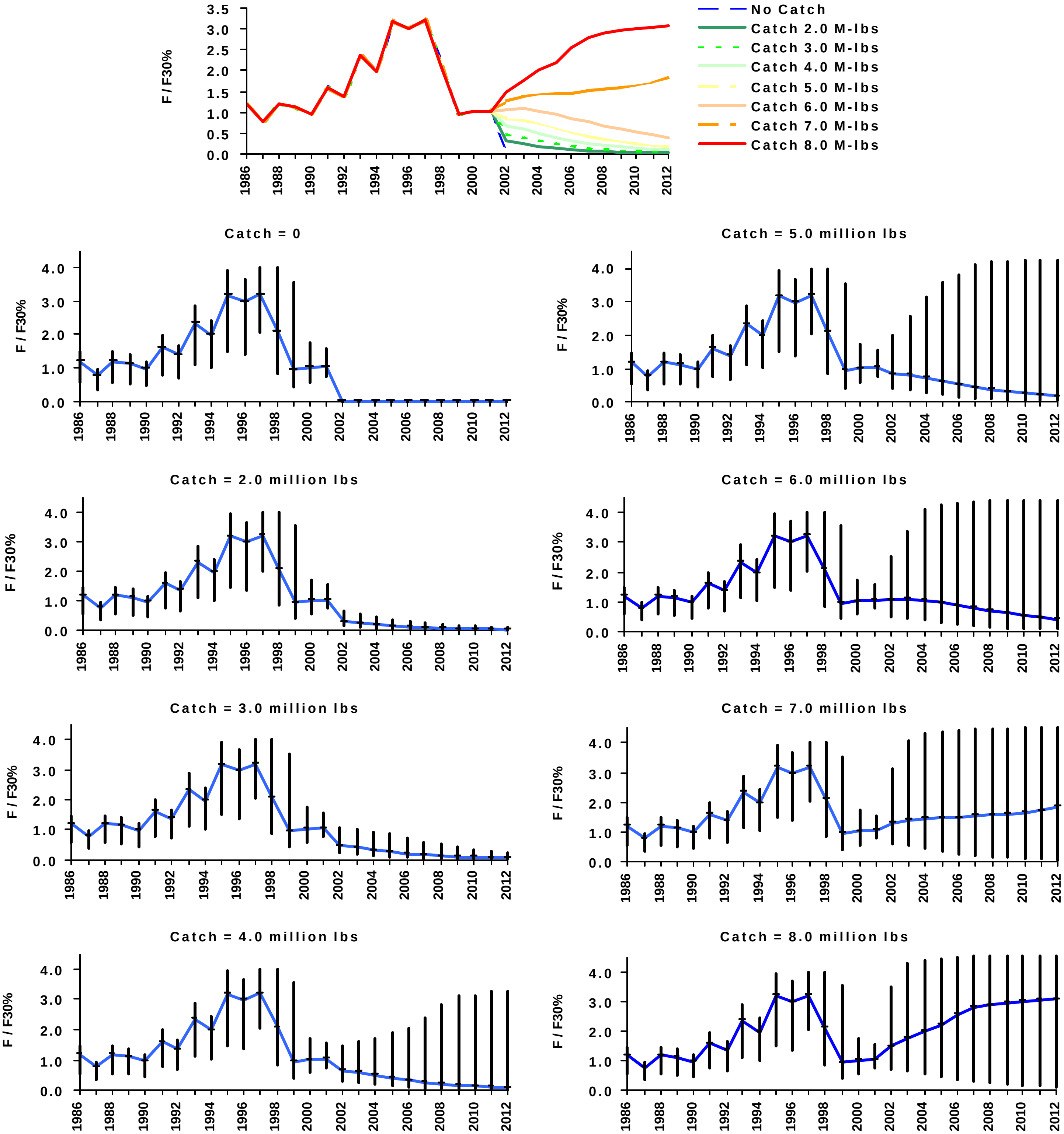



Figure 51. Historical and projected fishing mortality rate (F) relative to $F_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

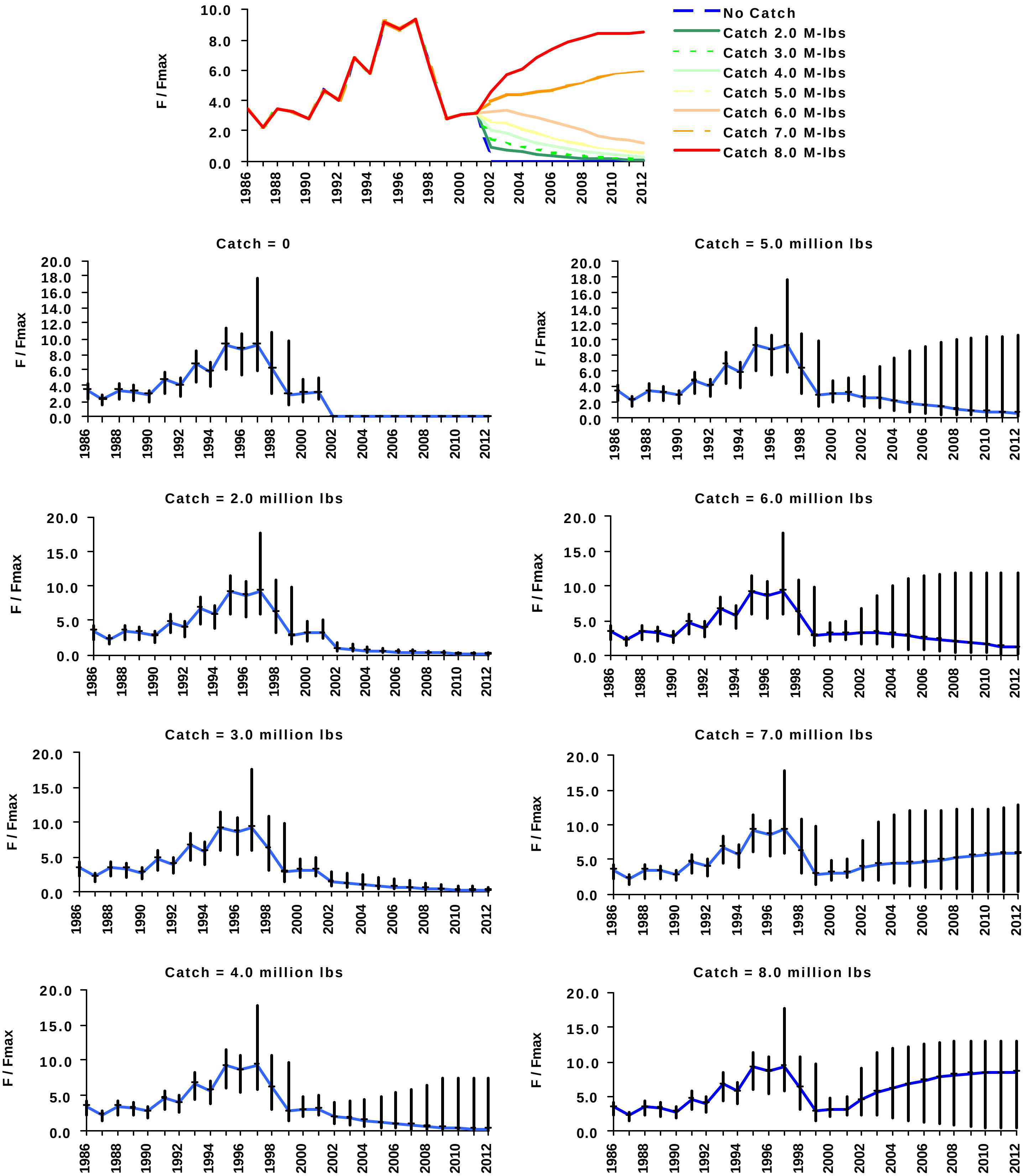



Figure 52. Historical and projected fishing mortality rate (F) relative to $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

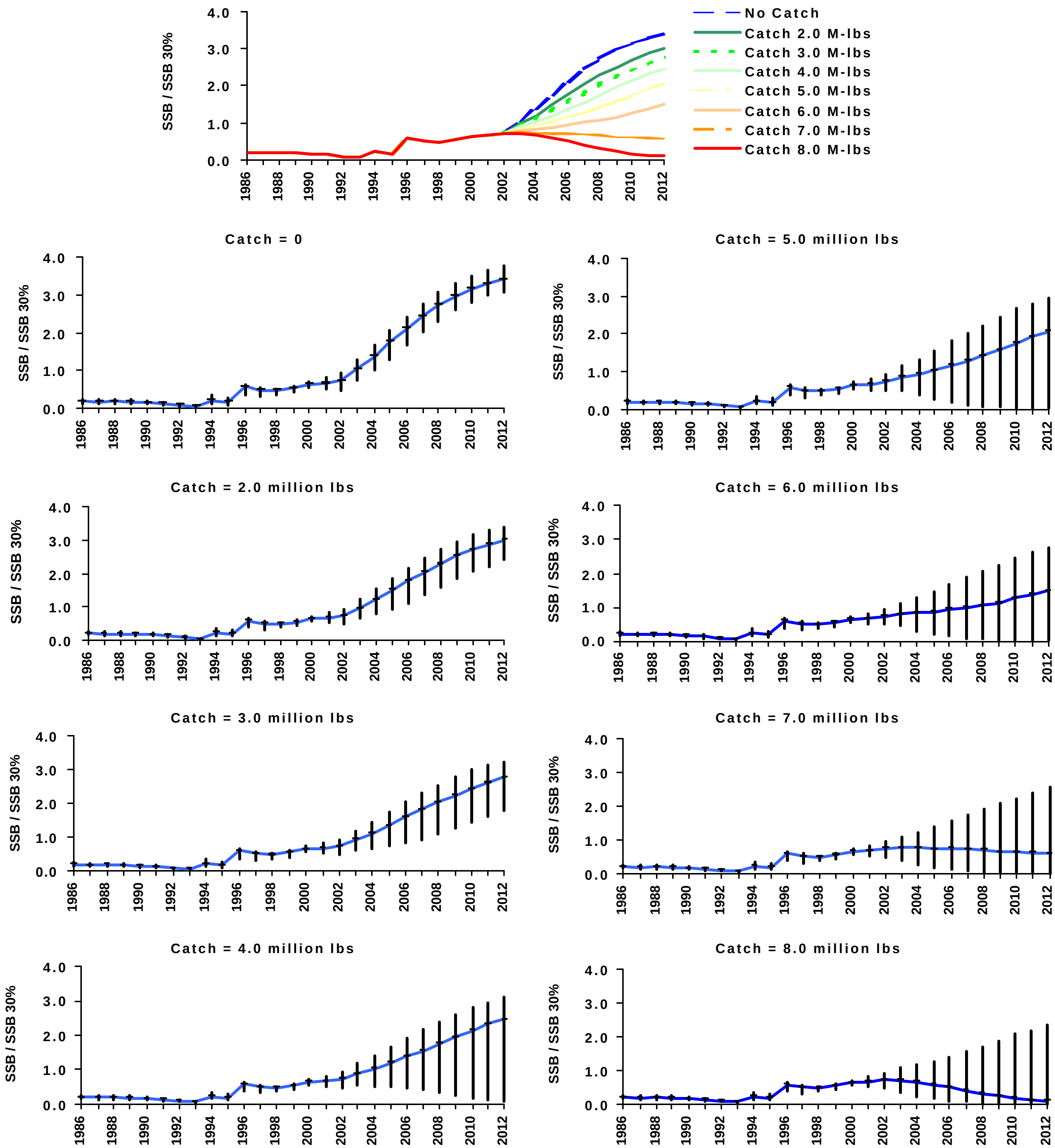



Figure 53. Historical and projected spawning stock biomass (SSB) relative to $SSB_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

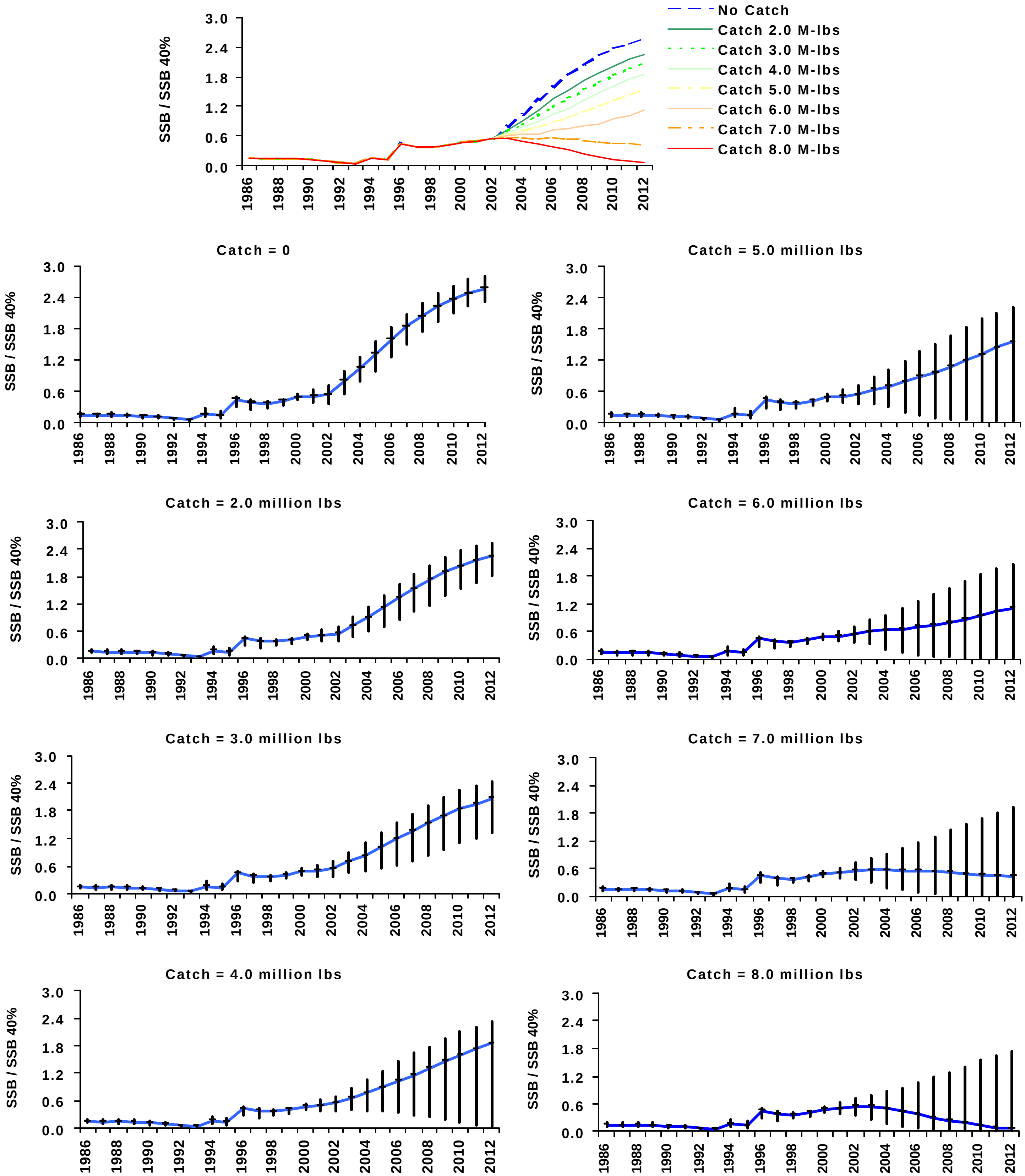



Figure 54. Historical and projected spawning stock biomass (SSB) relative to $SSB_{40\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

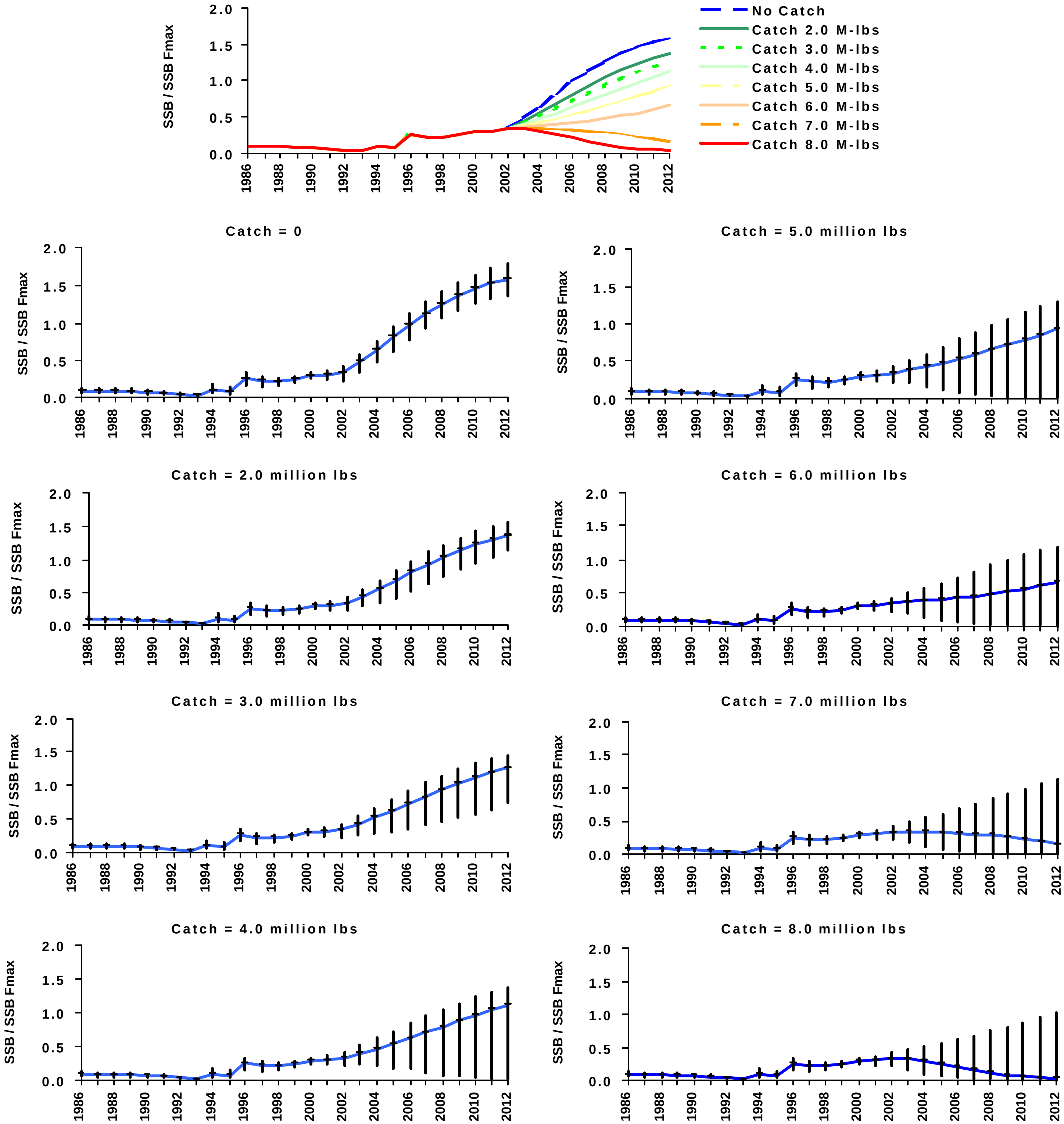



Figure 55. Historical and projected spawning stock biomass (SSB) relative to SSB at $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

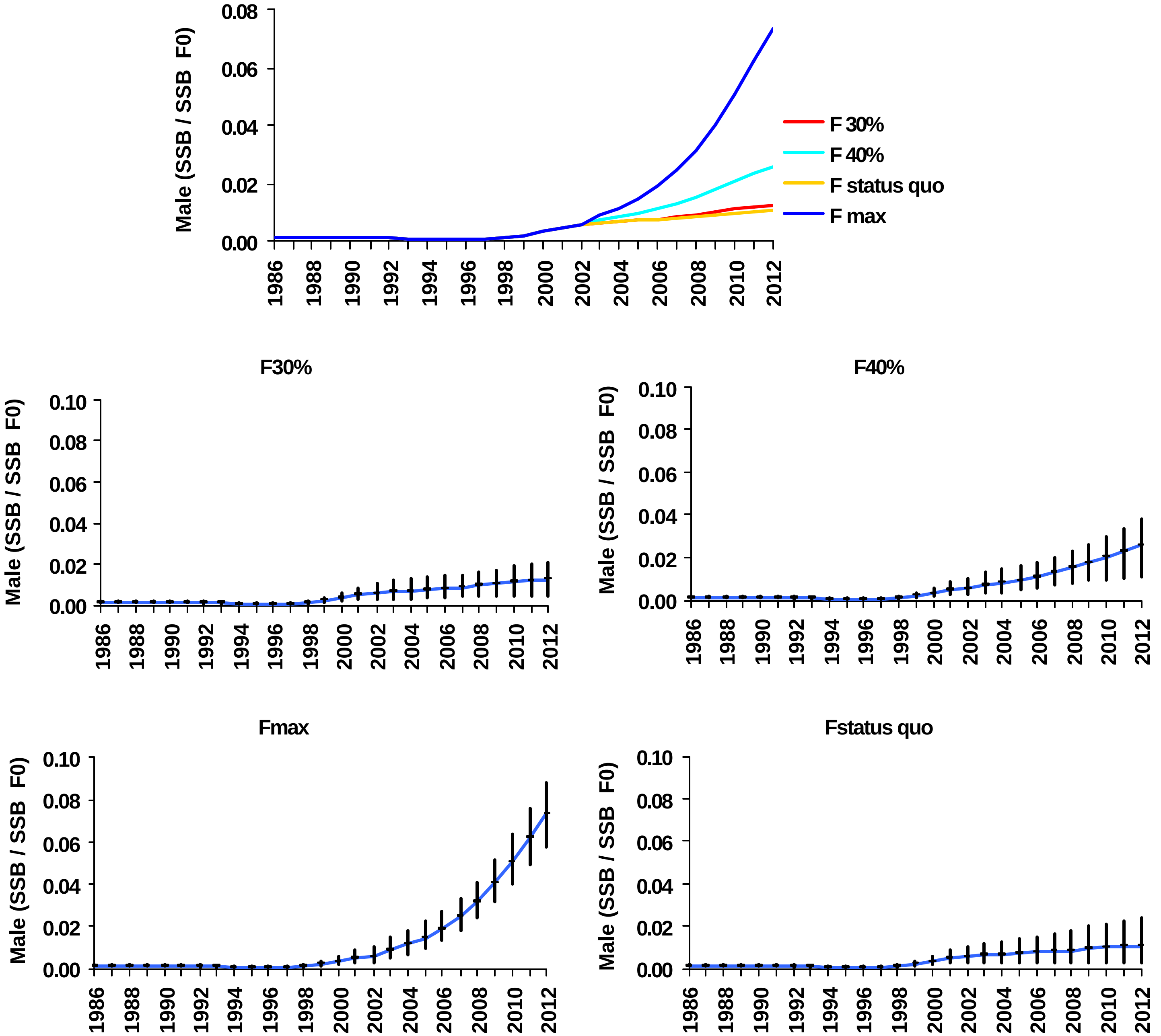



Figure 56. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

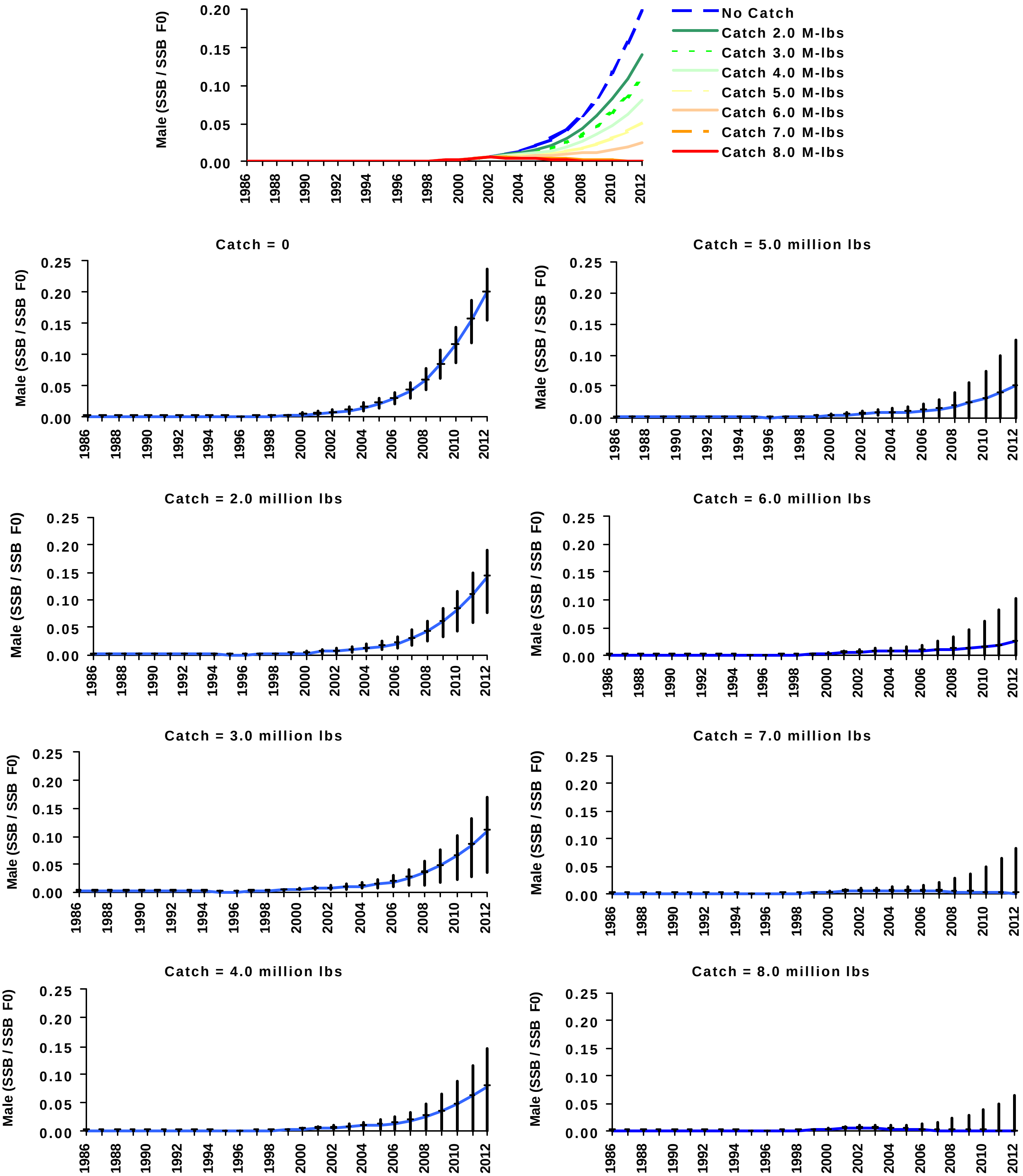



Figure 57. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

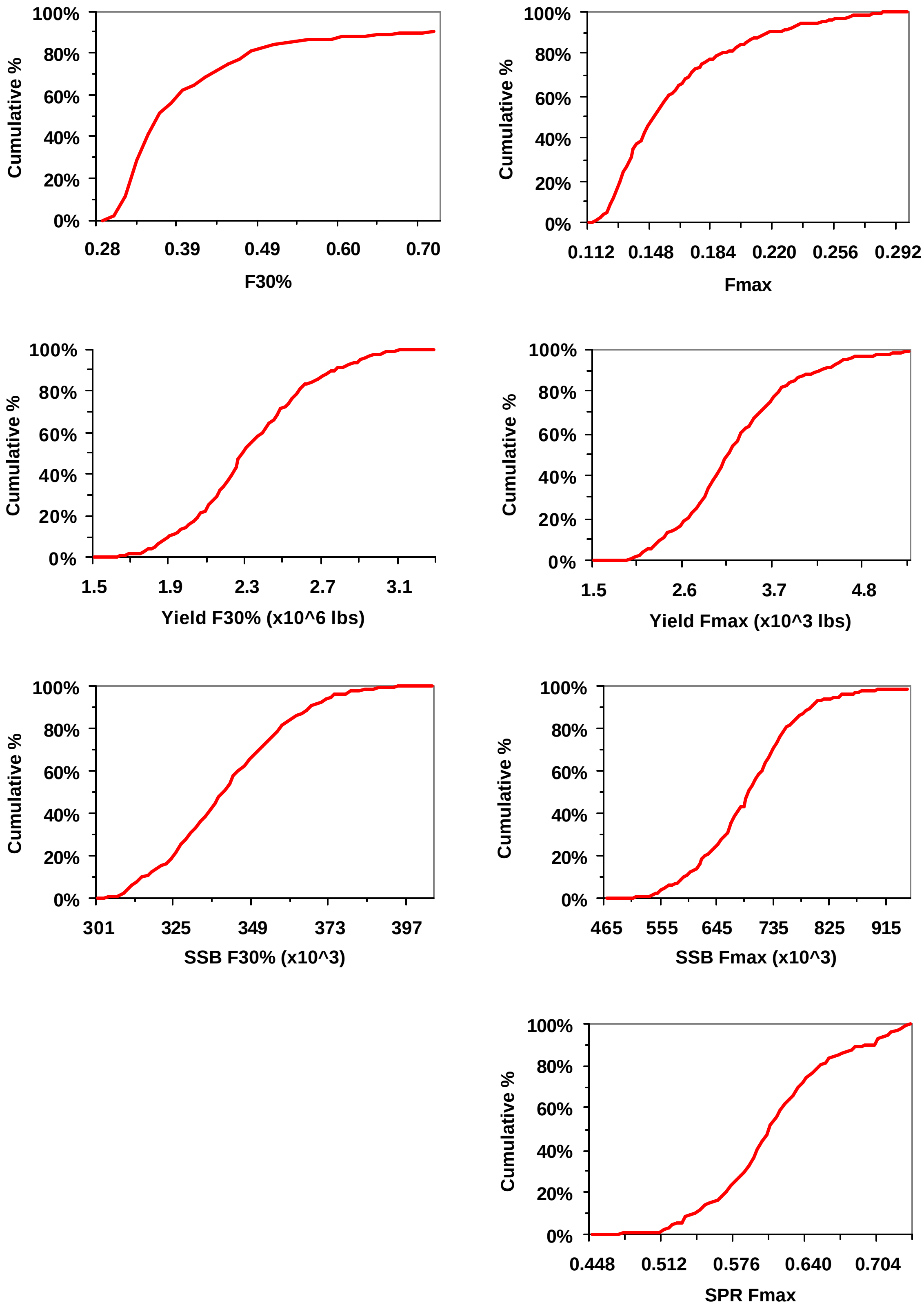
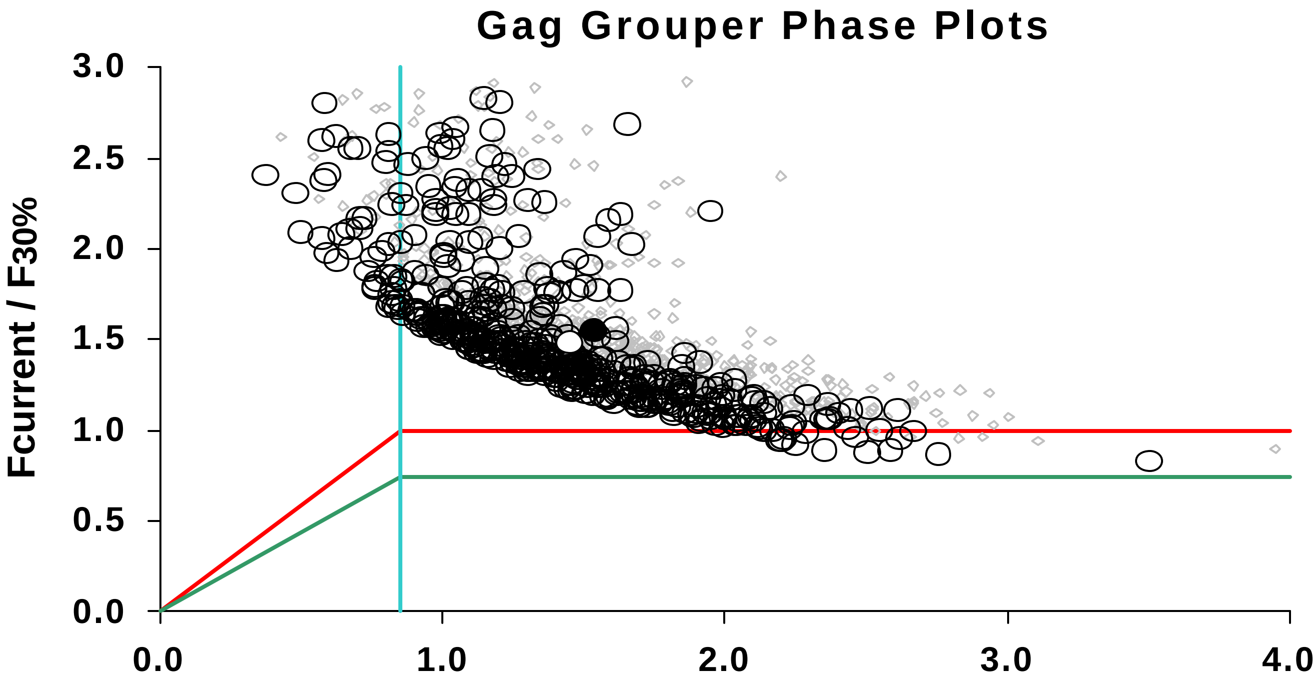



Figure 58. Cumulative frequency distributions for various reference statistics from bootstrapped estimates from the sensitivity VPA using the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size.



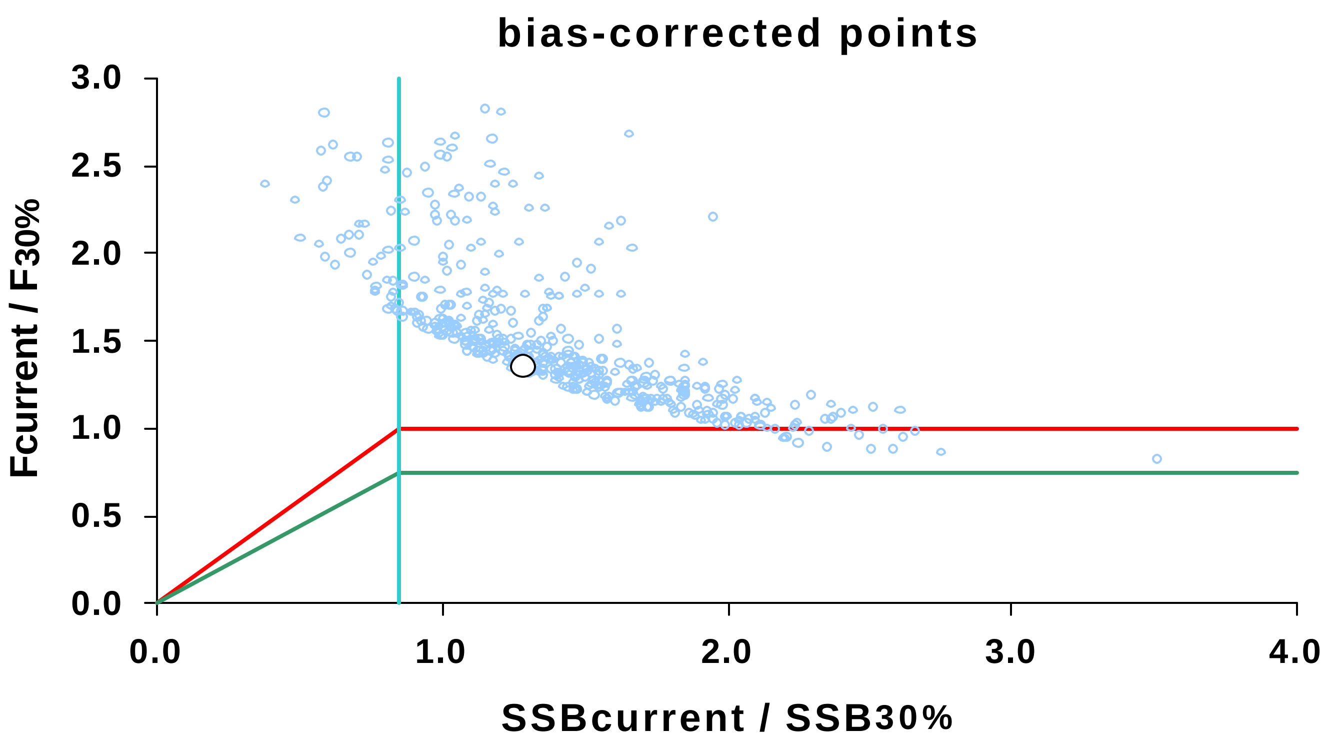




Figure 59. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to $SSB_{30\%}$ and $F_{30\%}$, respectively, from the analysis of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows bias corrected the individual bootstrap and the deterministic estimates.

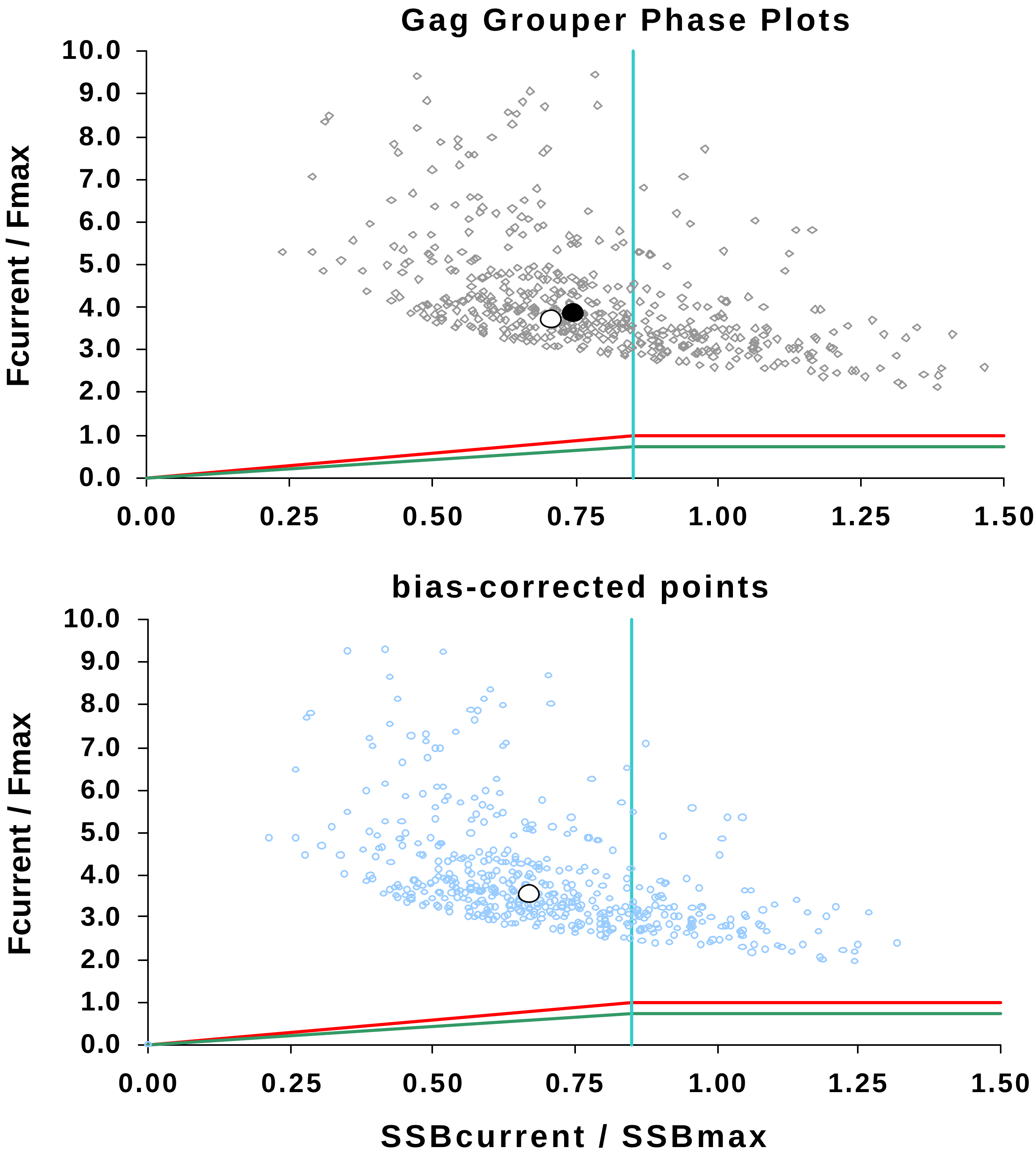



Figure 60. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to SSB and F at $F_{max}$ from the analysis of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows bias corrected the individual bootstrap and the deterministic estimates.

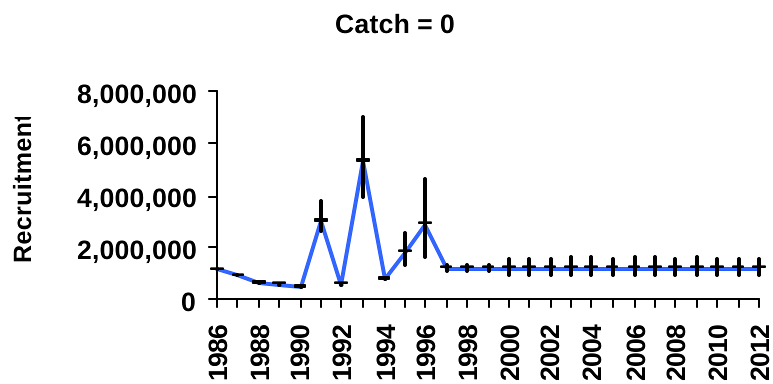



Figure 61. Historical and projected recruitment (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch after 2001.

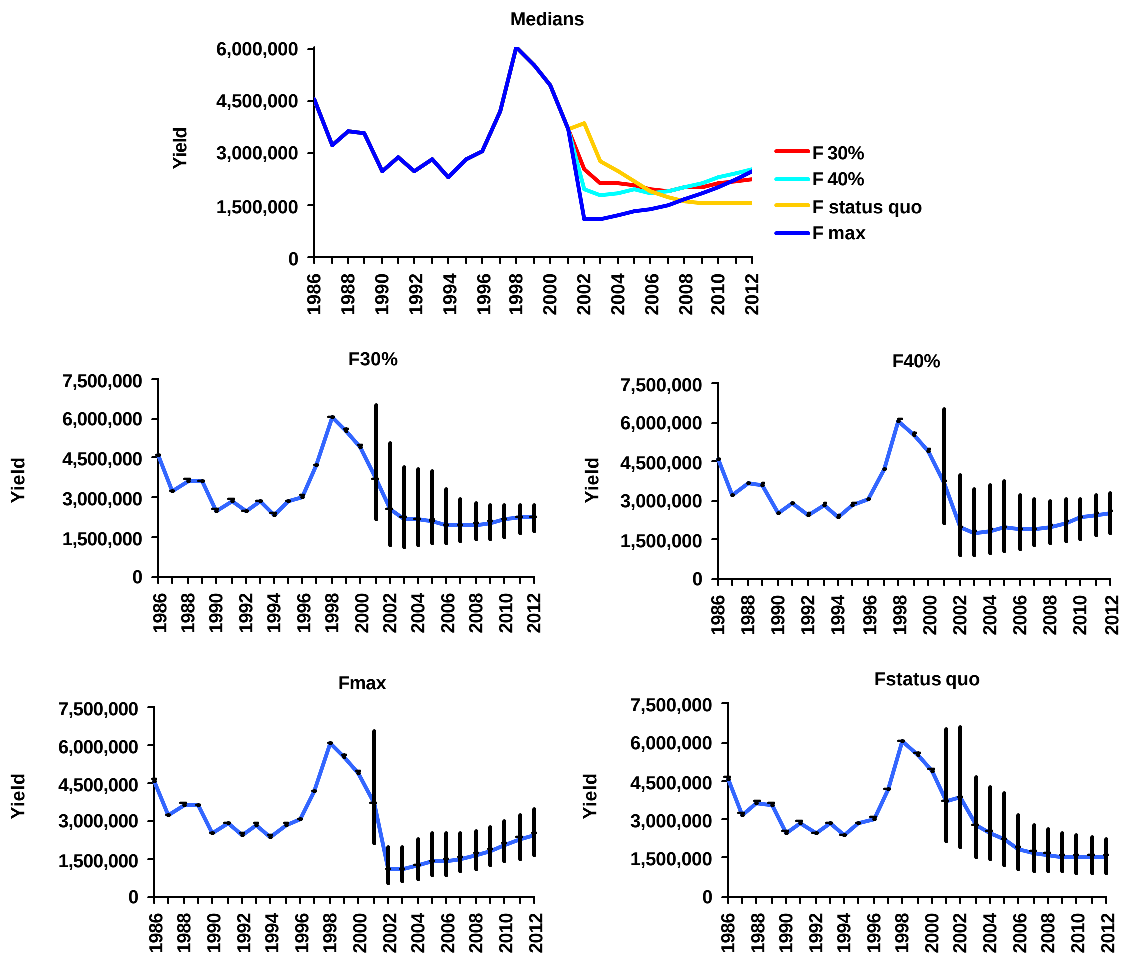



Figure 62. Historical and projected yield (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

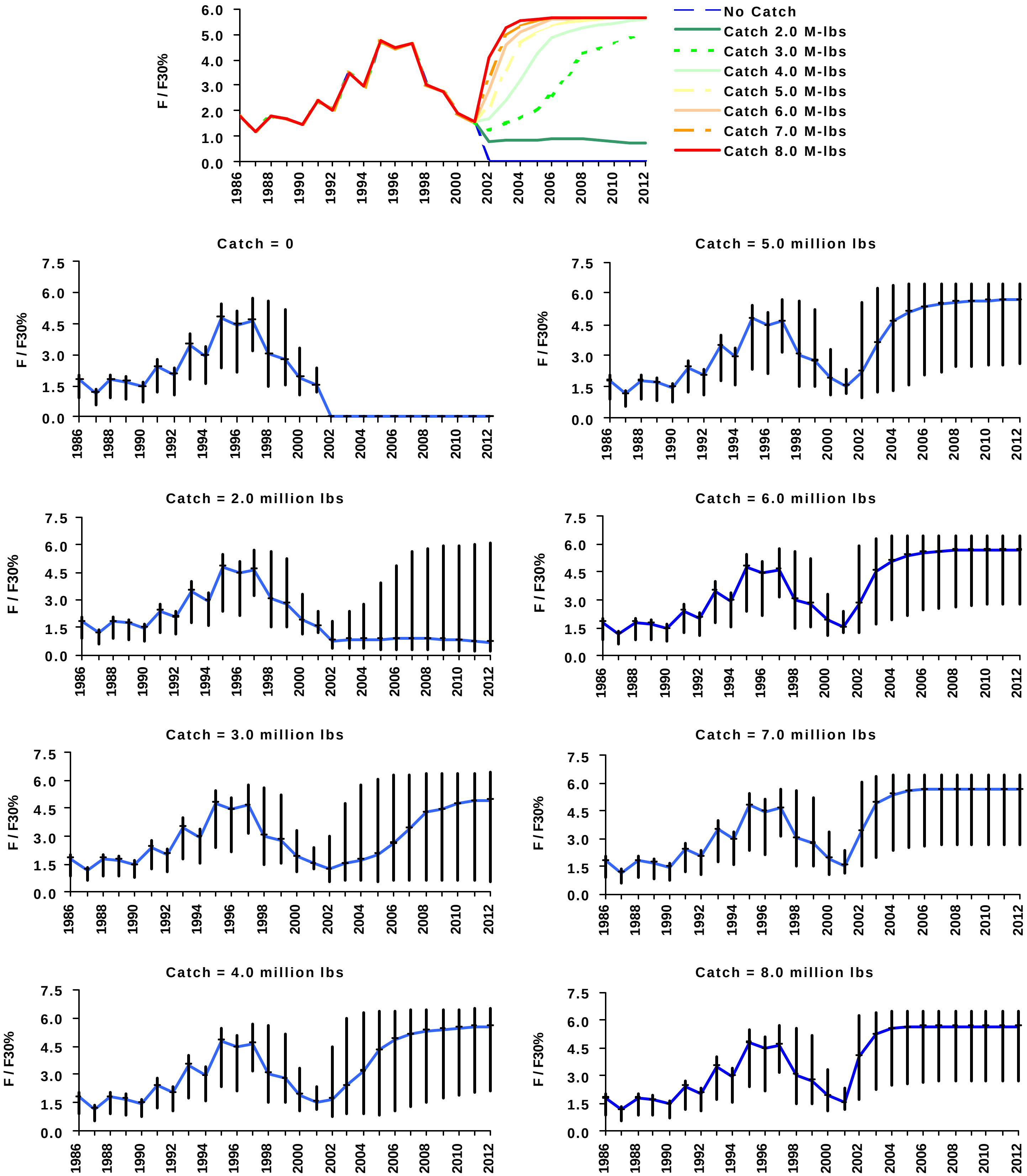



Figure 63. Historical and projected fishing mortality rate (F) relative to $F_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

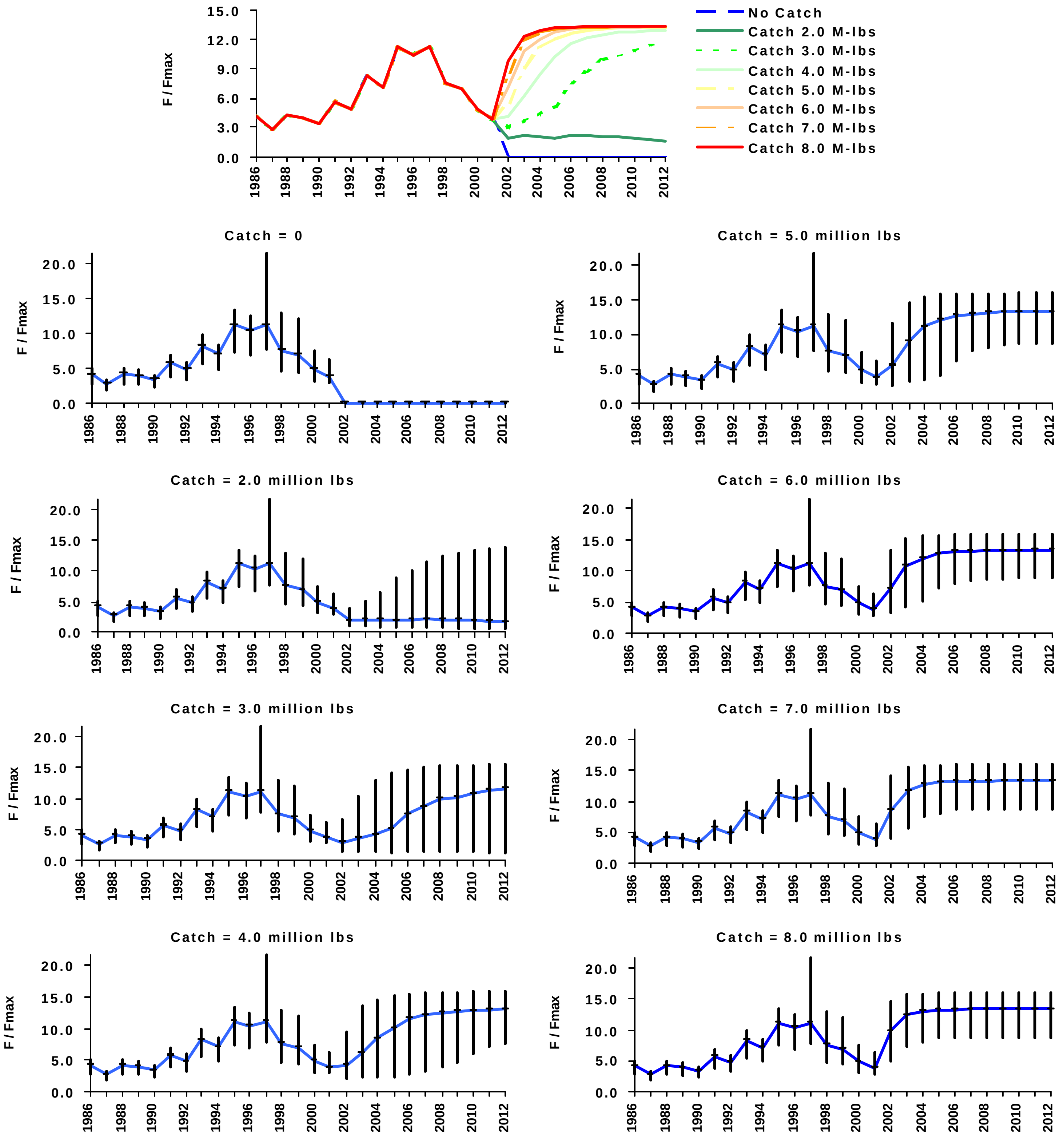



Figure 64. Historical and projected fishing mortality rate (F) relative to $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

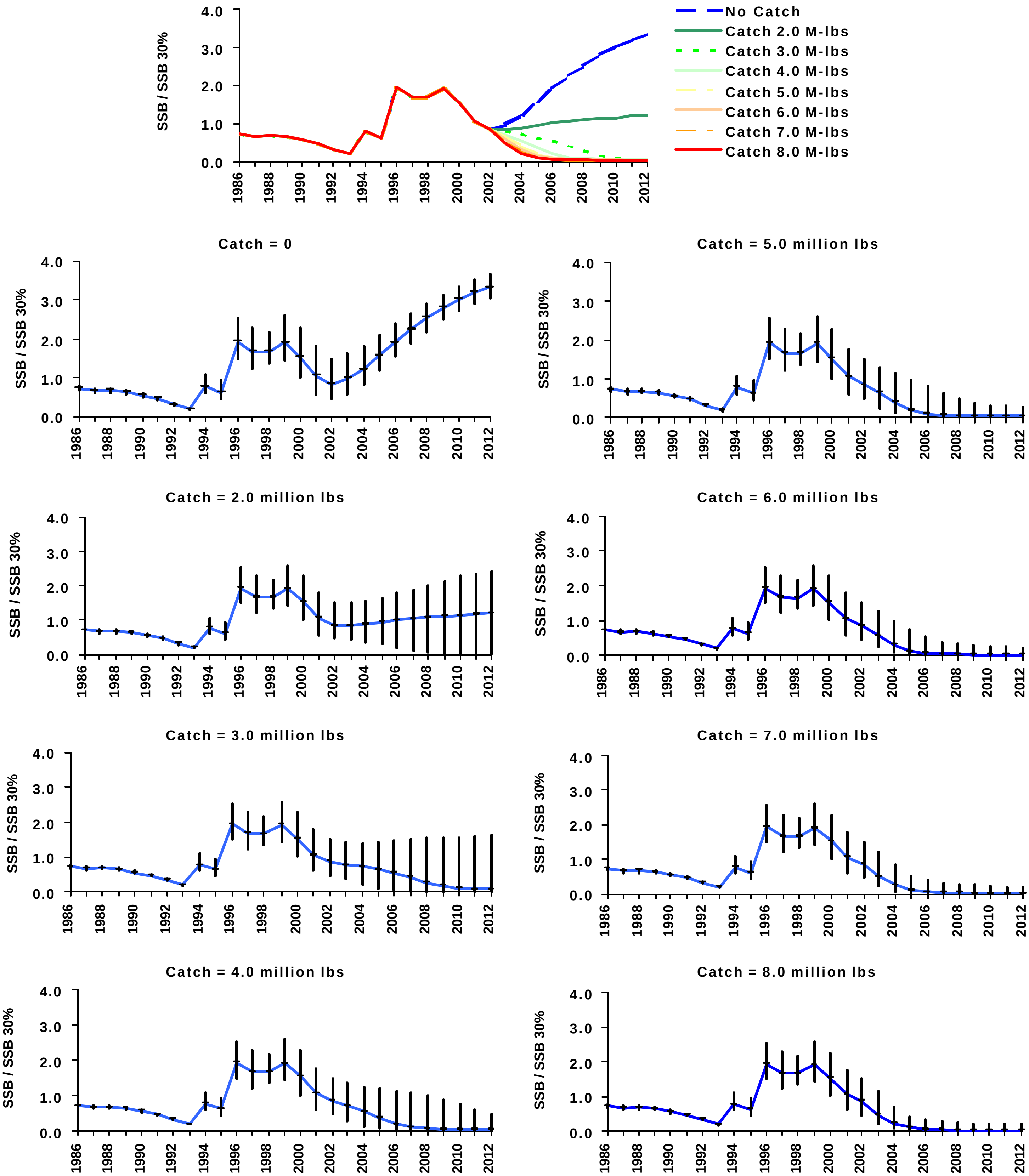



Figure 65. Historical and projected spawning stock biomass (SSB) relative to $SSB_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

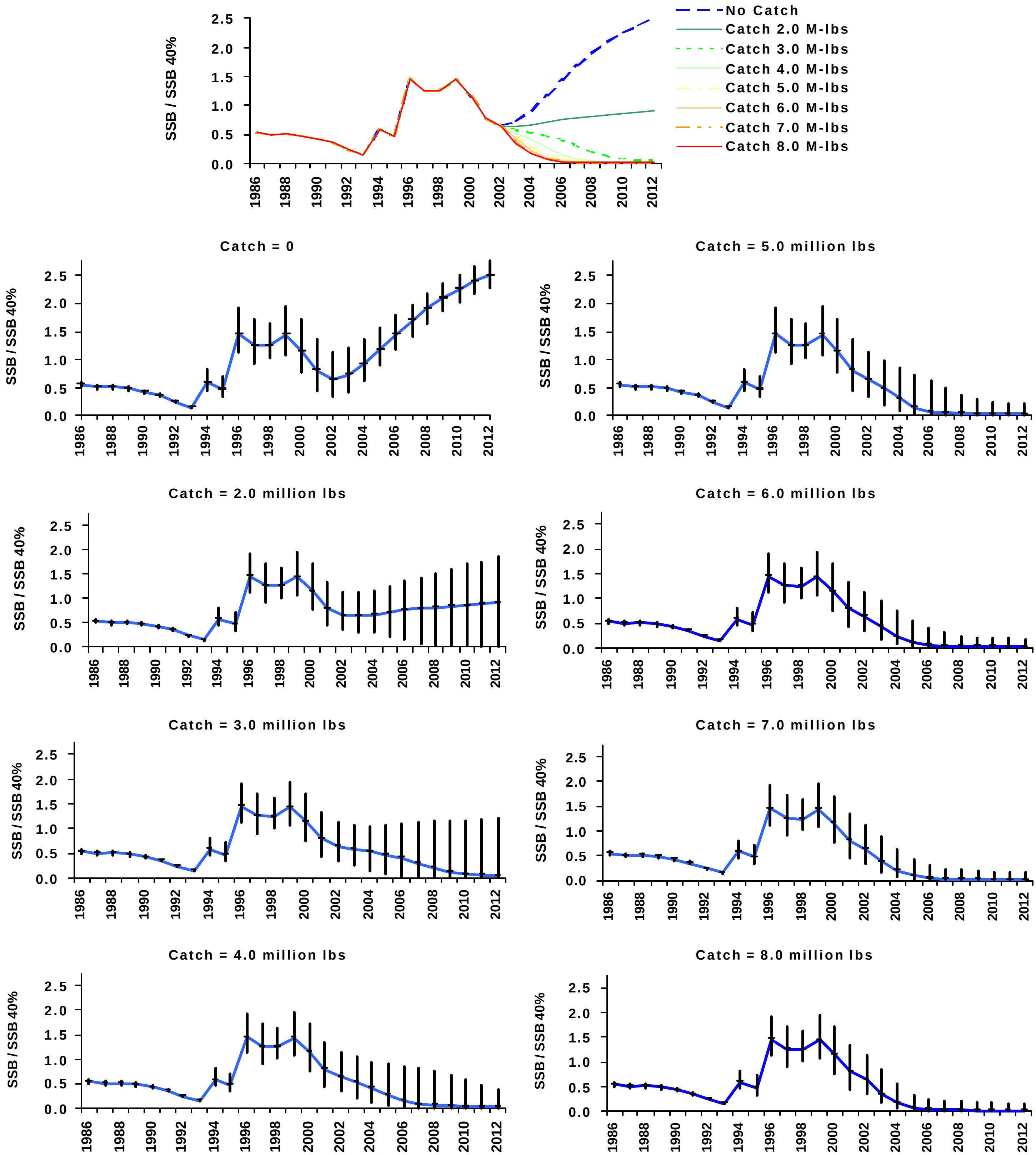



Figure 66. Historical and projected spawning stock biomass (SSB) relative to $SSB_{40\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

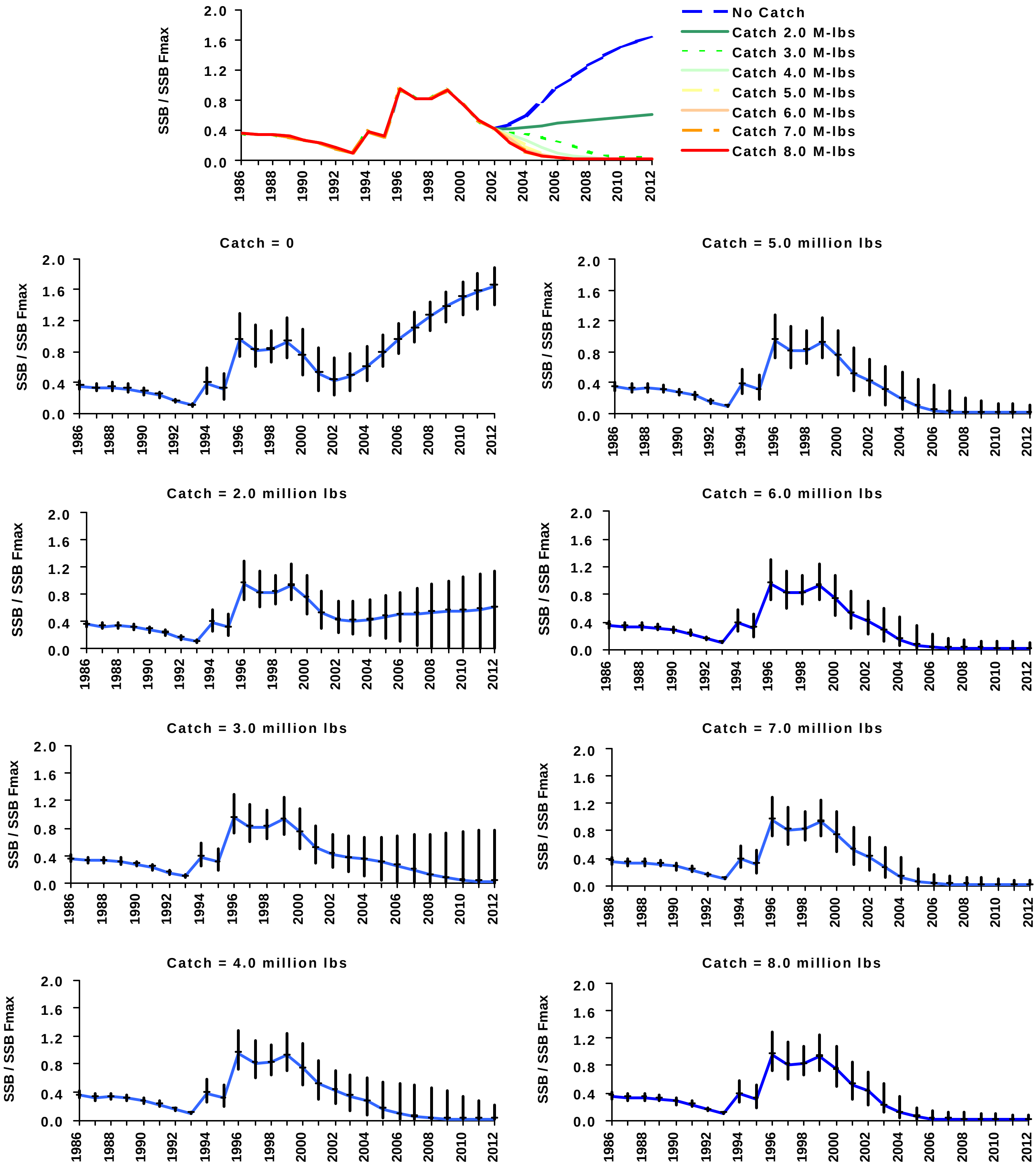



Figure 67. Historical and projected spawning stock biomass (SSB) relative to SSB at $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

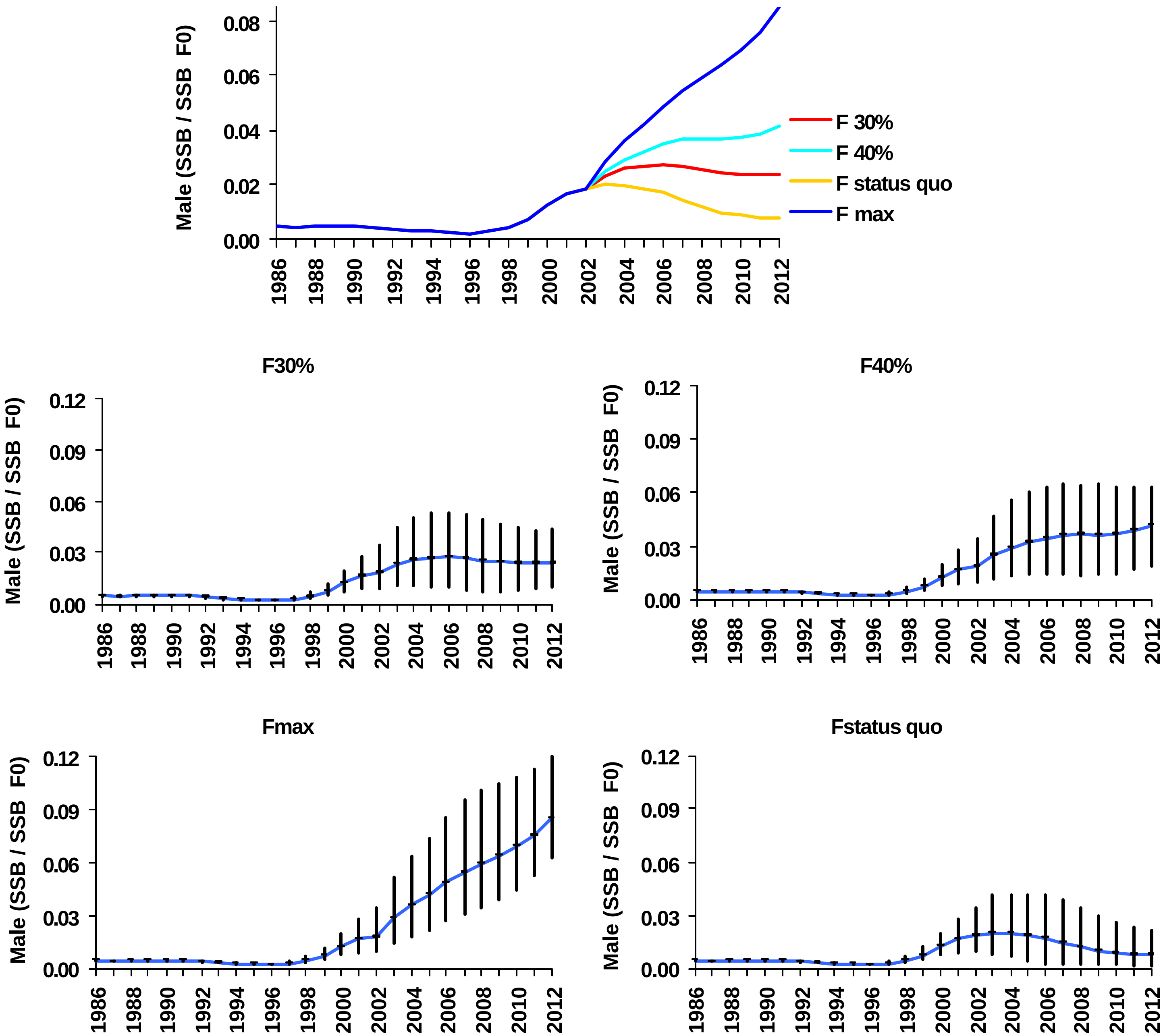



Figure 68. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

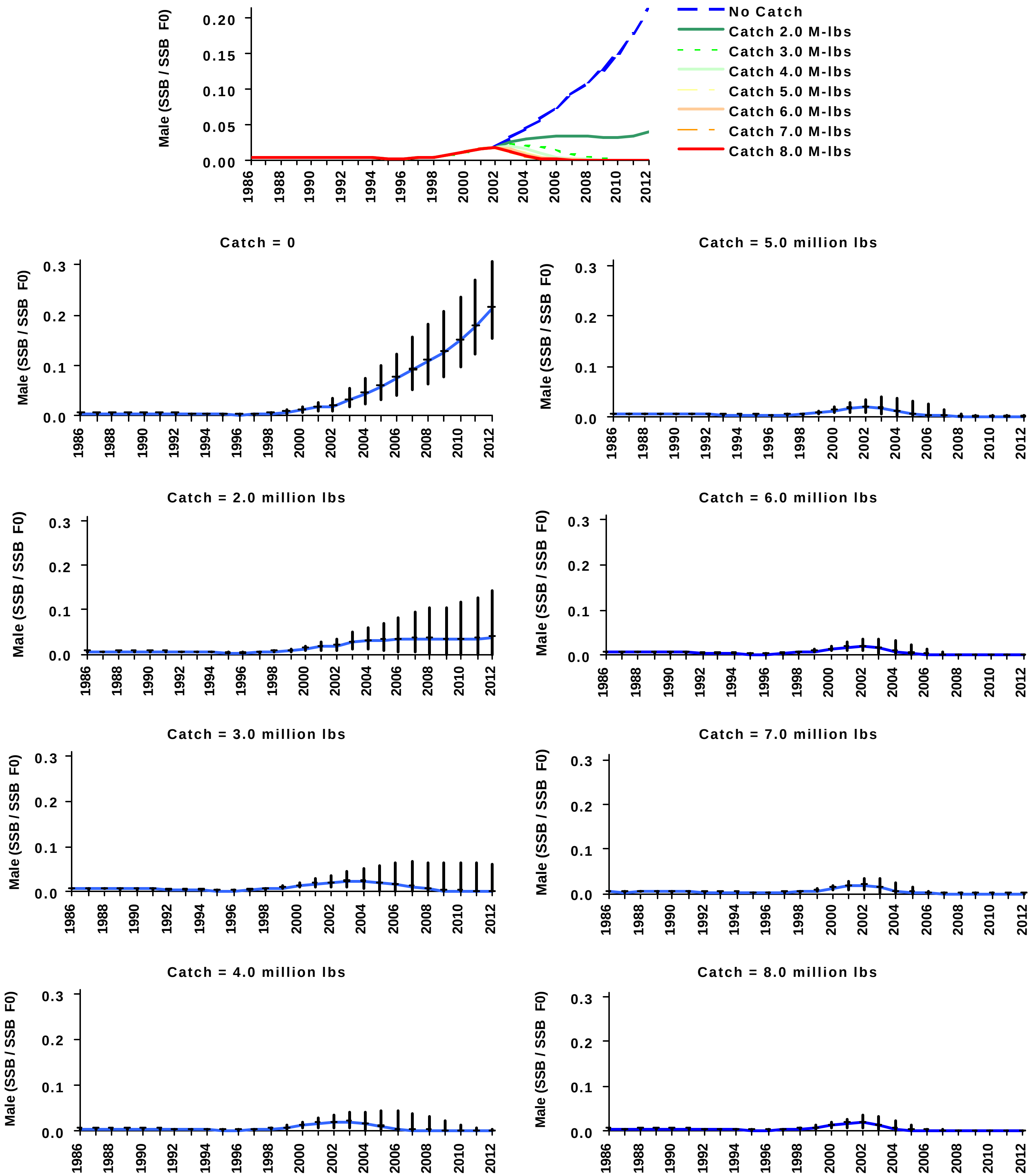



Figure 69. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA of the RMM catch-at-age with average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

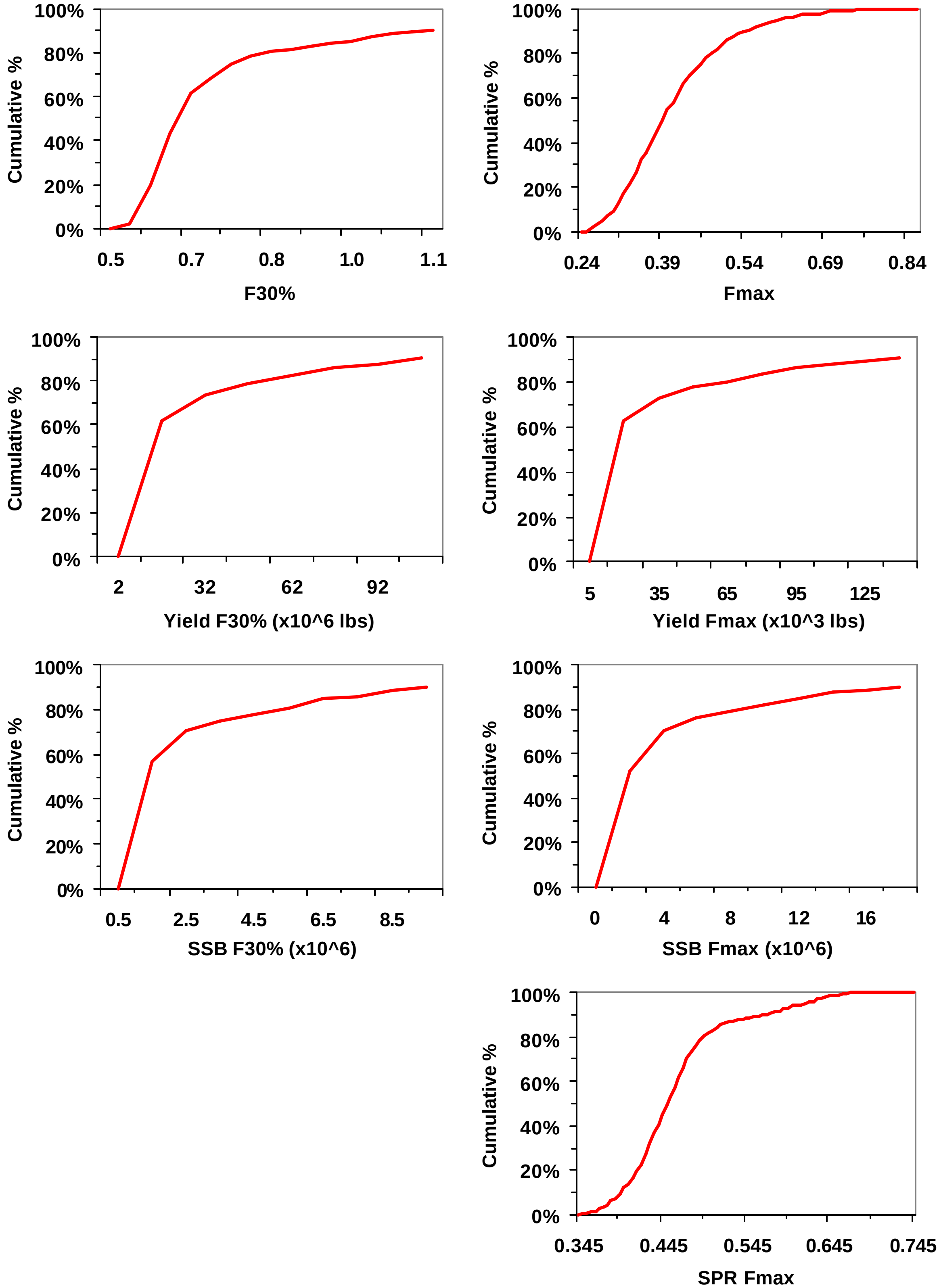



Figure 70. Cumulative frequency distributions for various reference statistics from bootstrapped estimates from the sensitivity VPA using the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size.

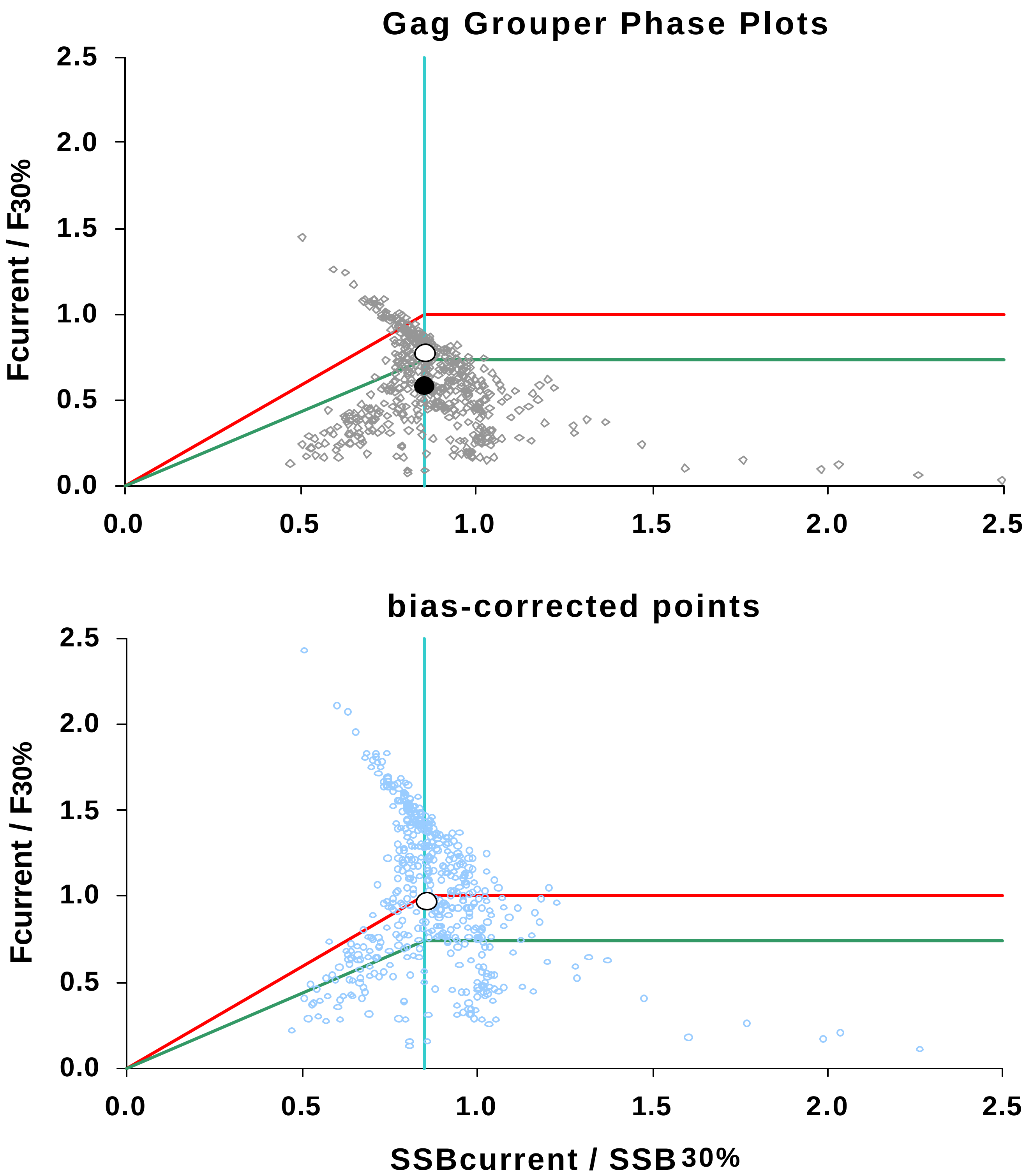



Figure 71. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to $SSB_{30\%}$ and $F_{30\%}$, respectively, from the analysis of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

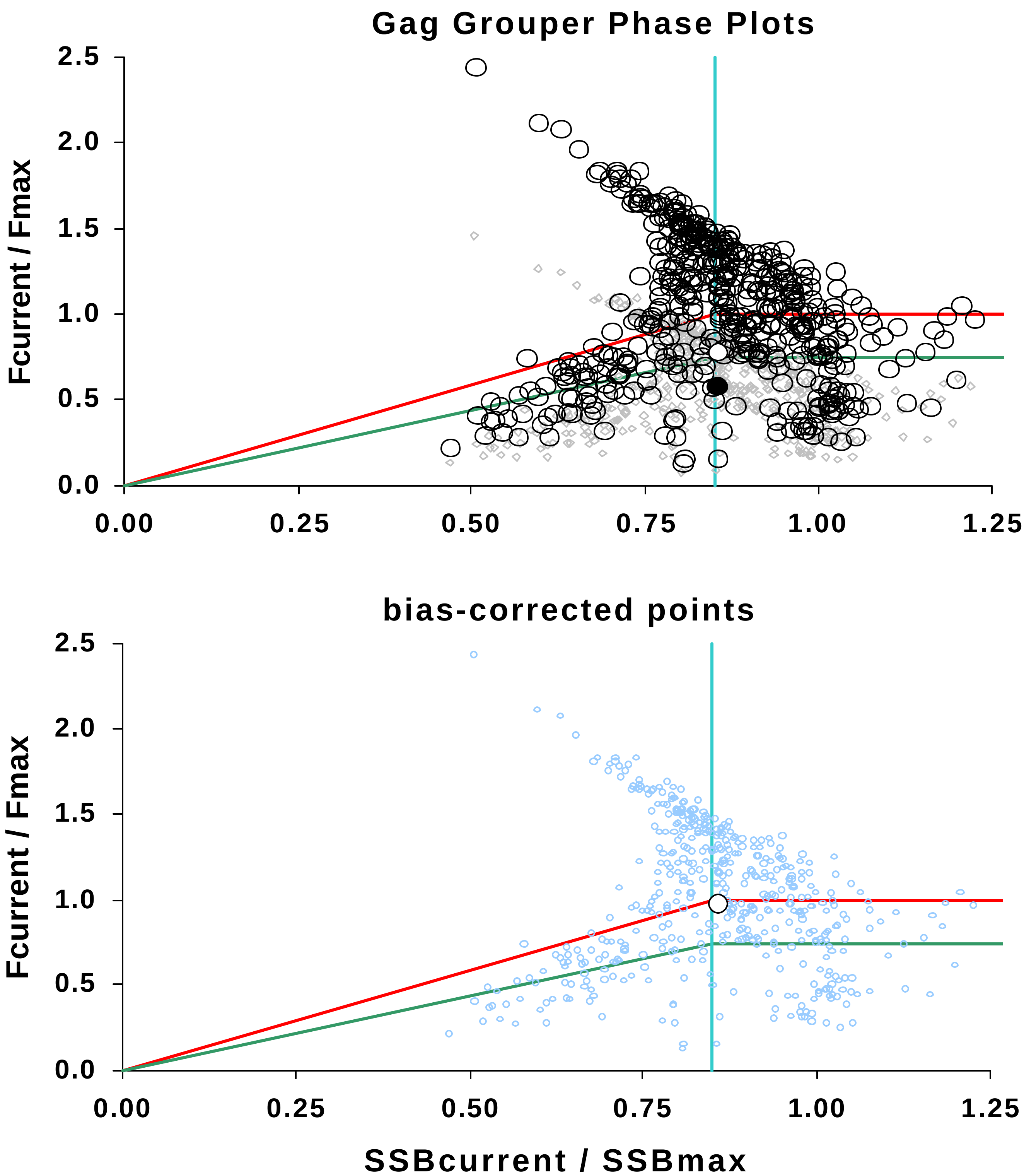



Figure 72. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to SSB and F at $F_{max}$ from the analysis of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

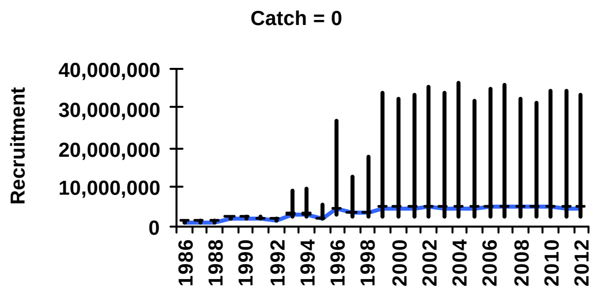



Figure 73. Historical and projected recruitment (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch after 2001.

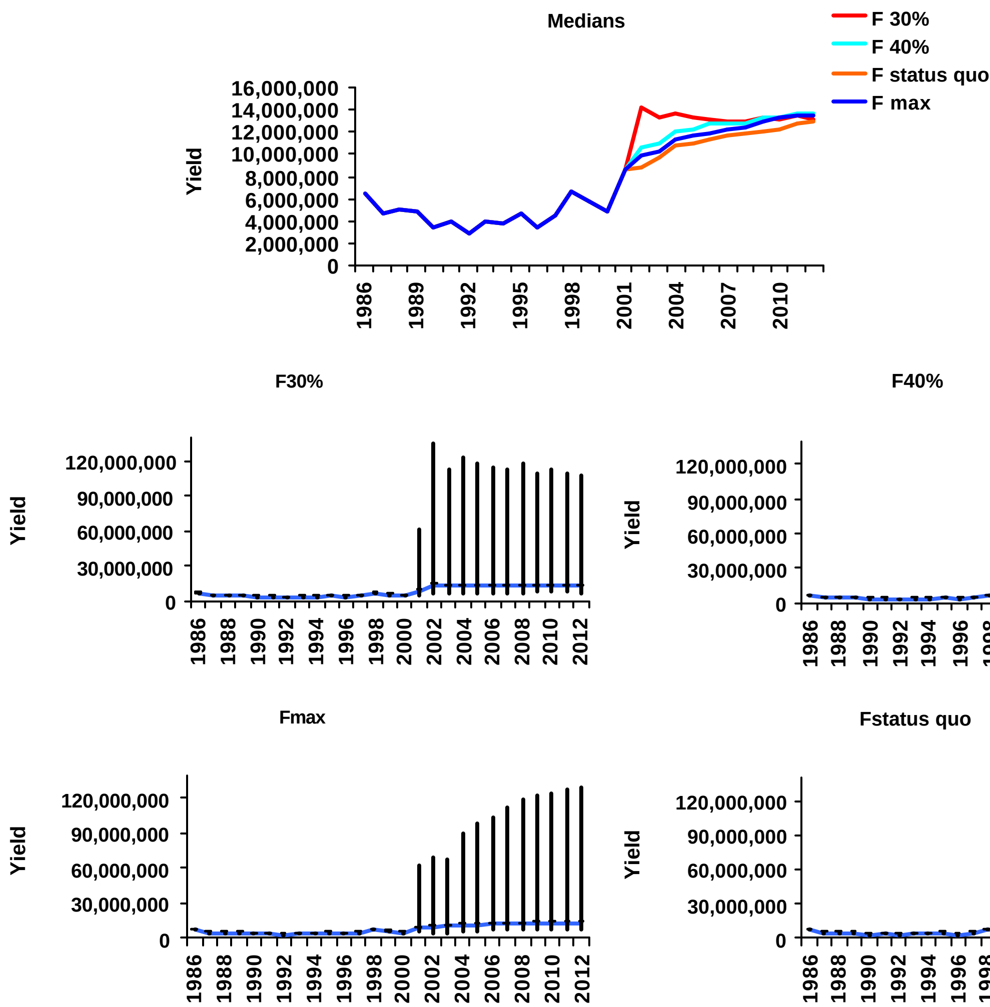



Figure 74. Historical and projected yield (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

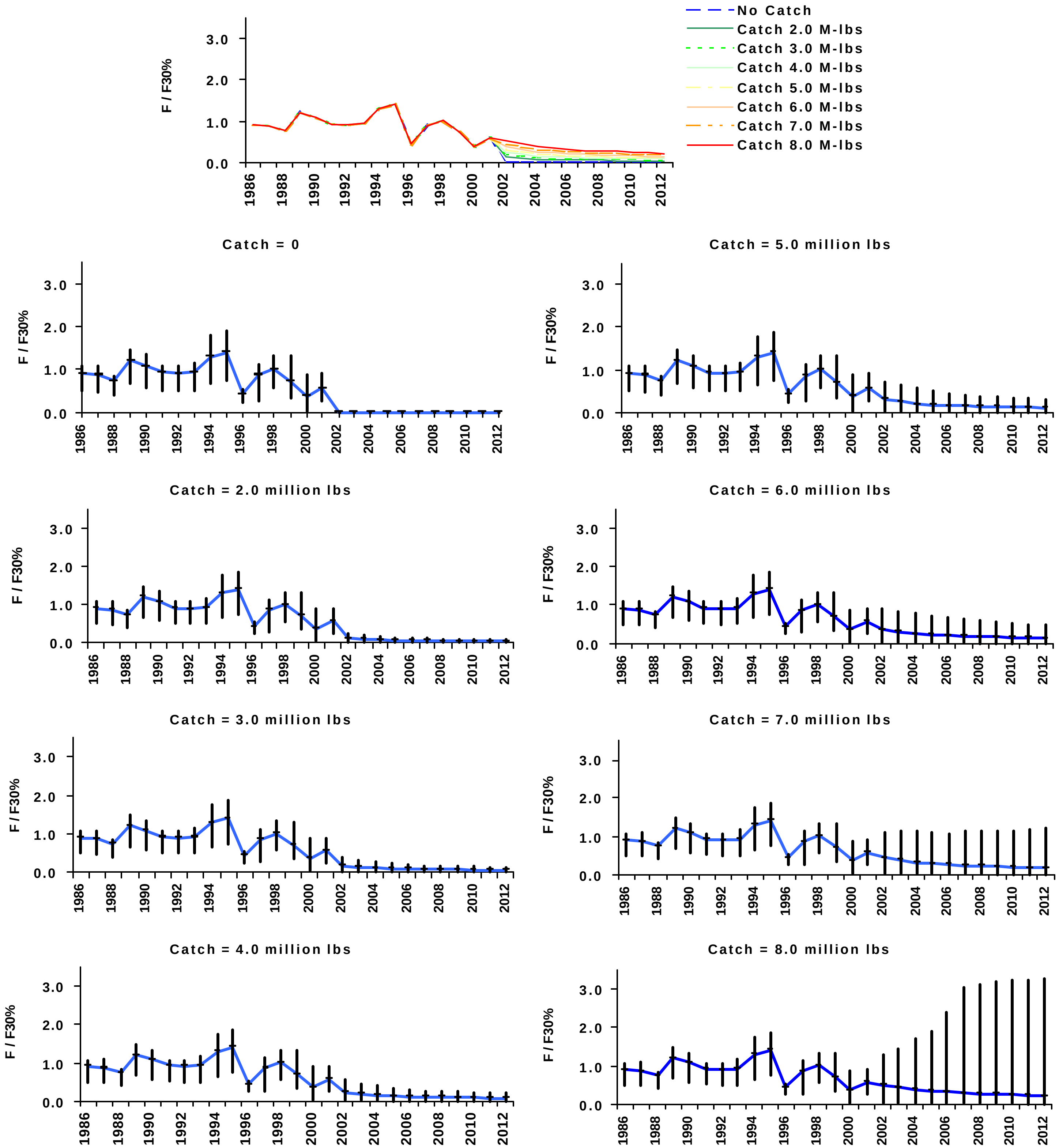



Figure 75. Historical and projected fishing mortality rate (F) relative to $F_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

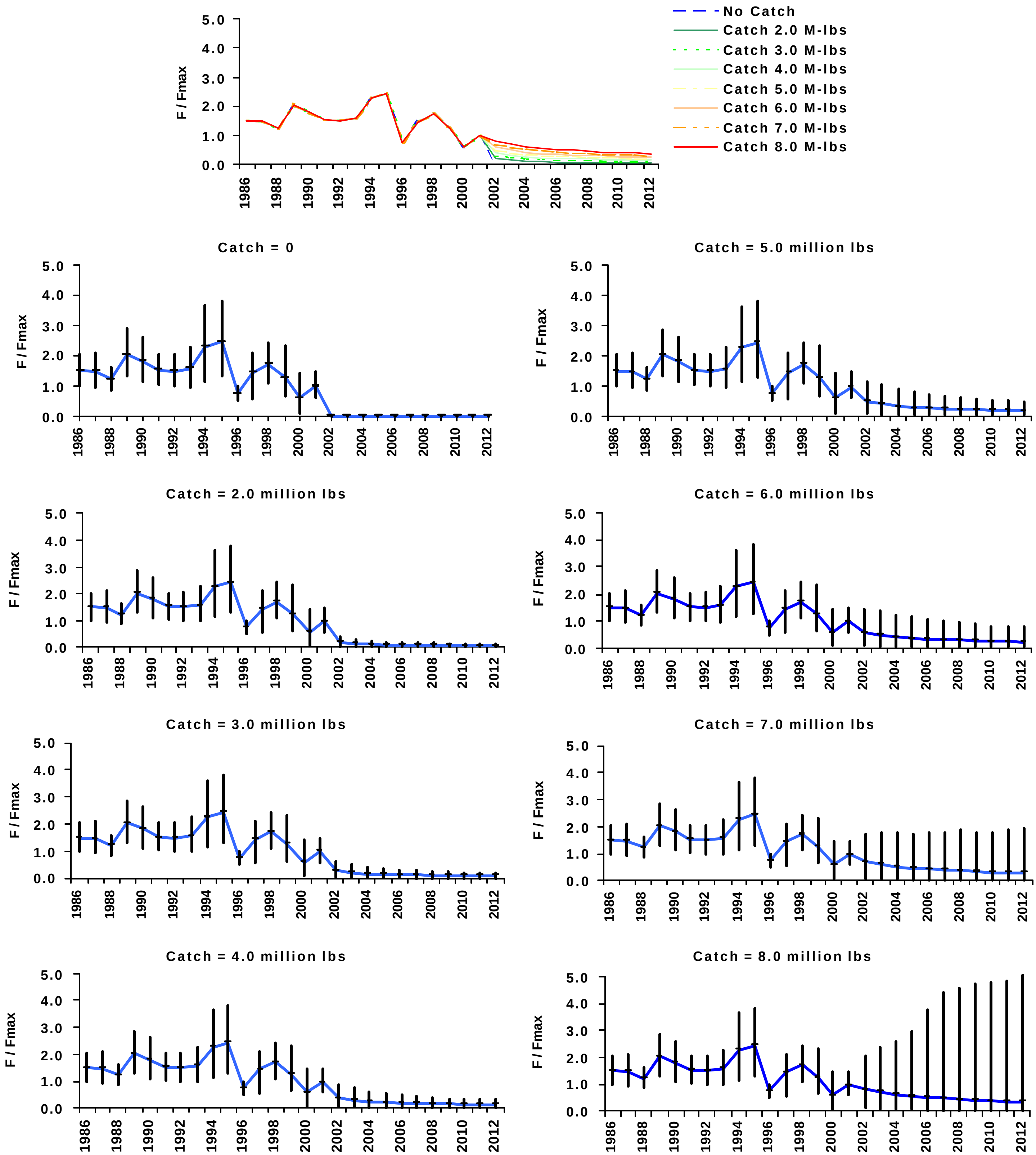



Figure 76. Historical and projected fishing mortality rate (F) relative to $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

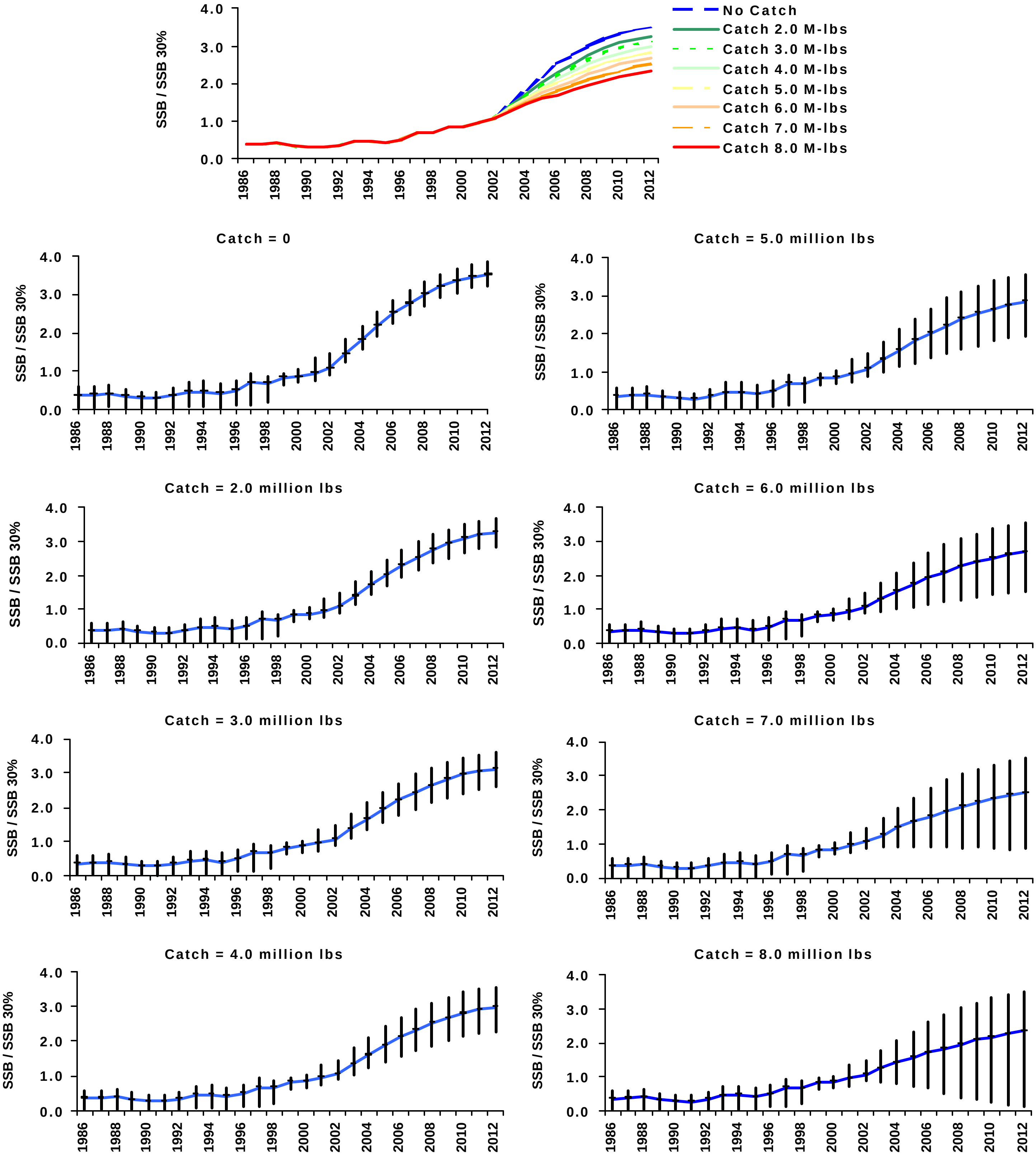



Figure 77. Historical and projected spawning stock biomass (SSB) relative to $SSB_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

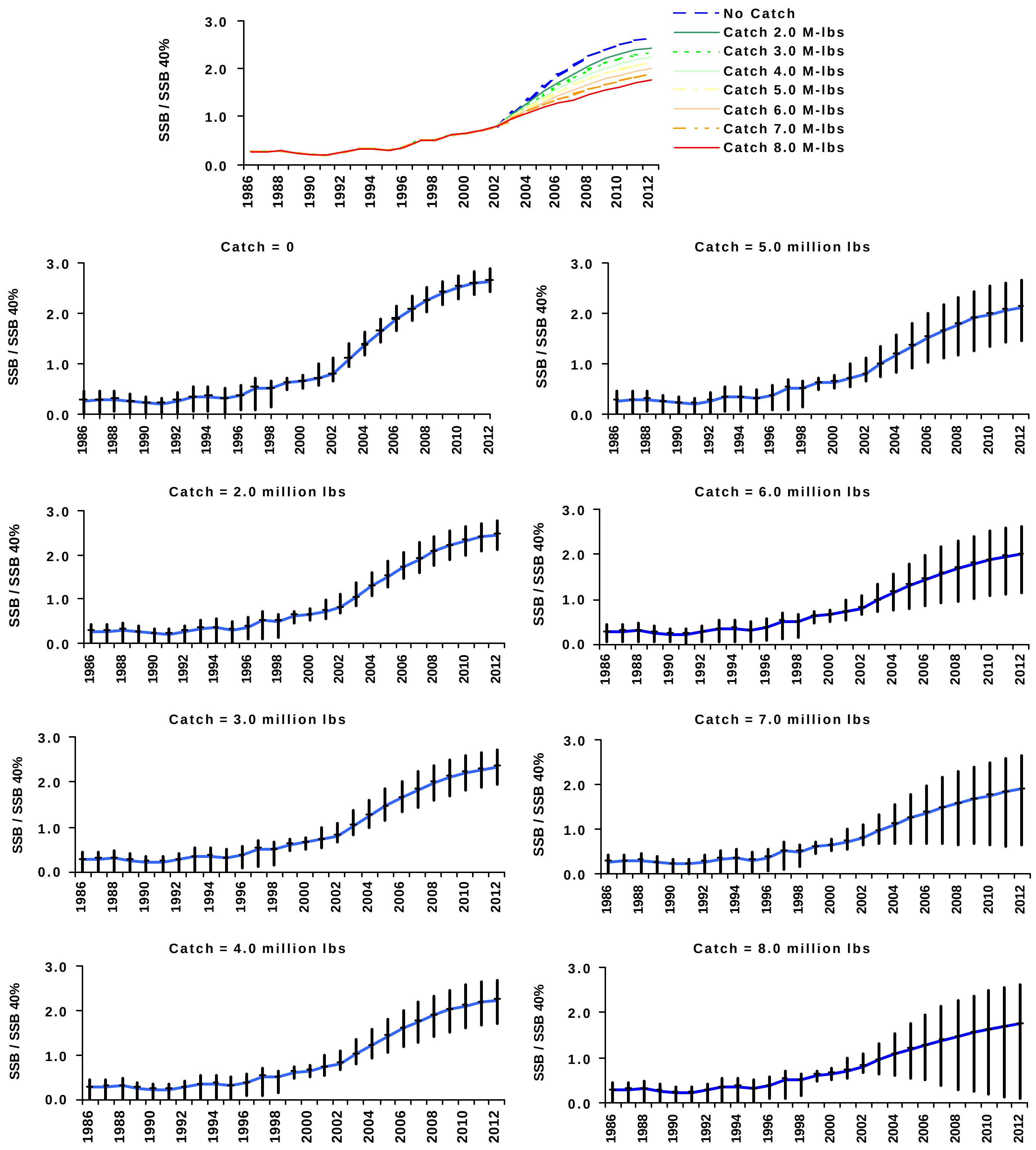



Figure 78. Historical and projected spawning stock biomass (SSB) relative to $SSB_{40\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

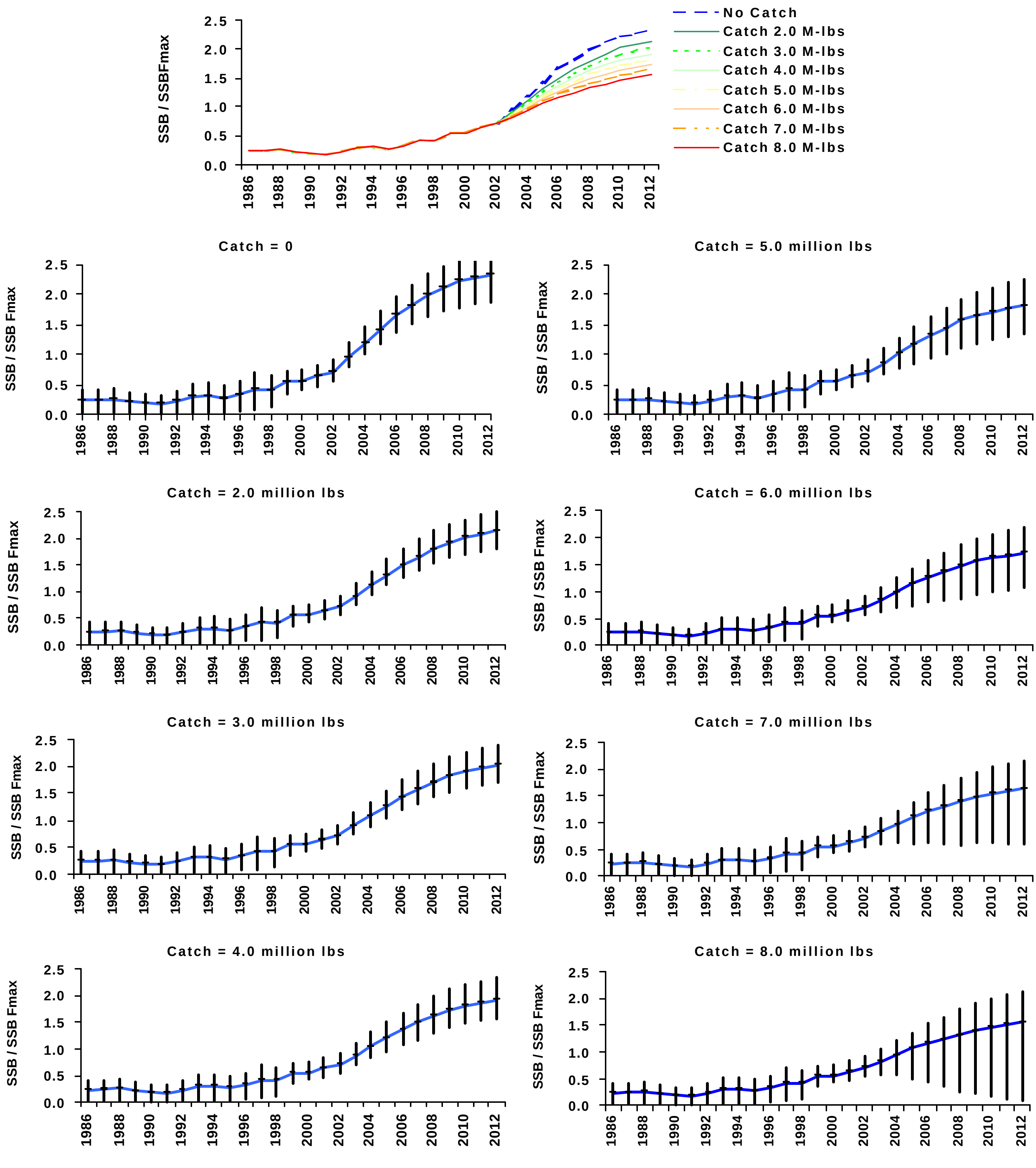



Figure 79. Historical and projected spawning stock biomass (SSB) relative to SSB at $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

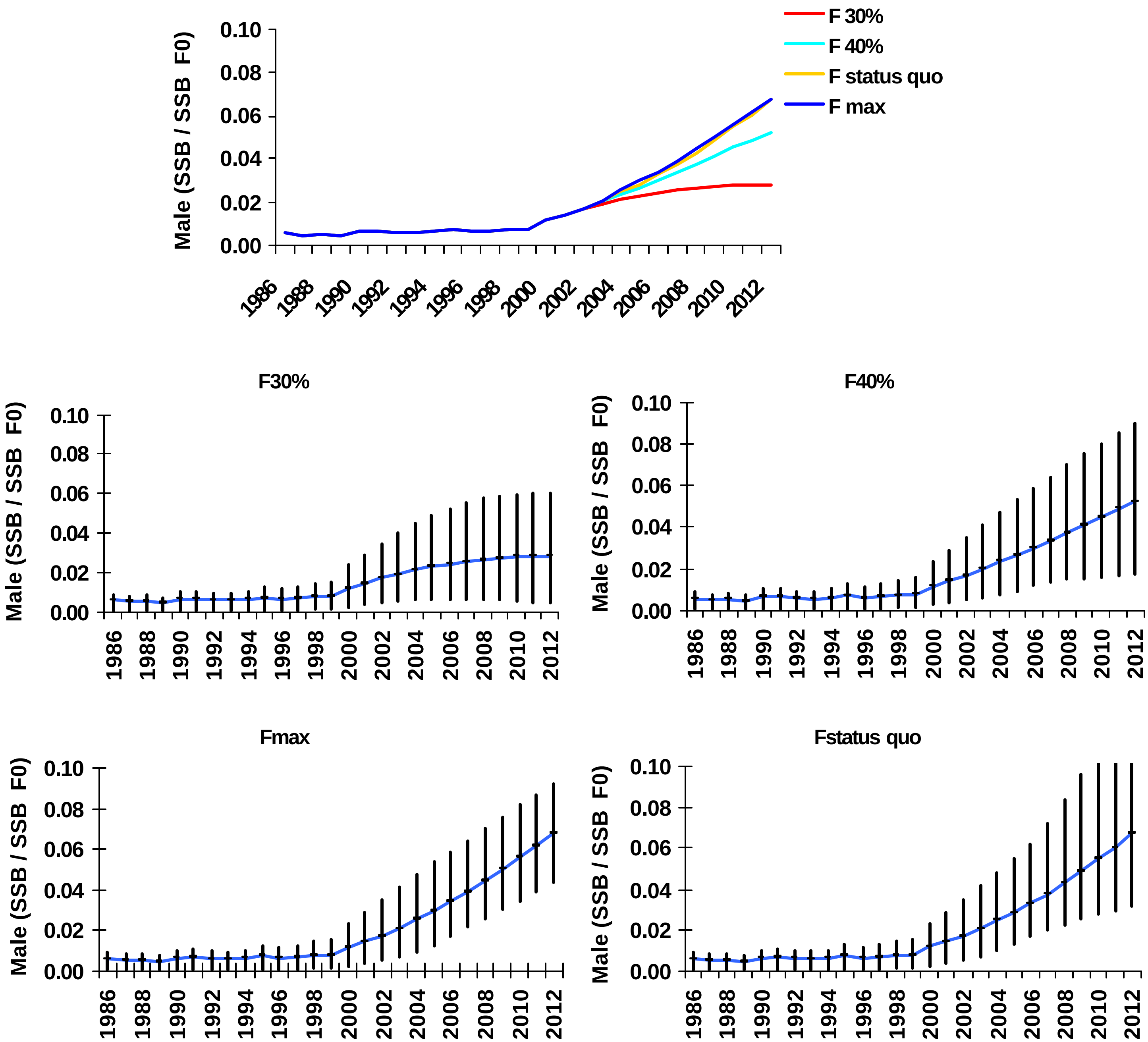



Figure 80. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$

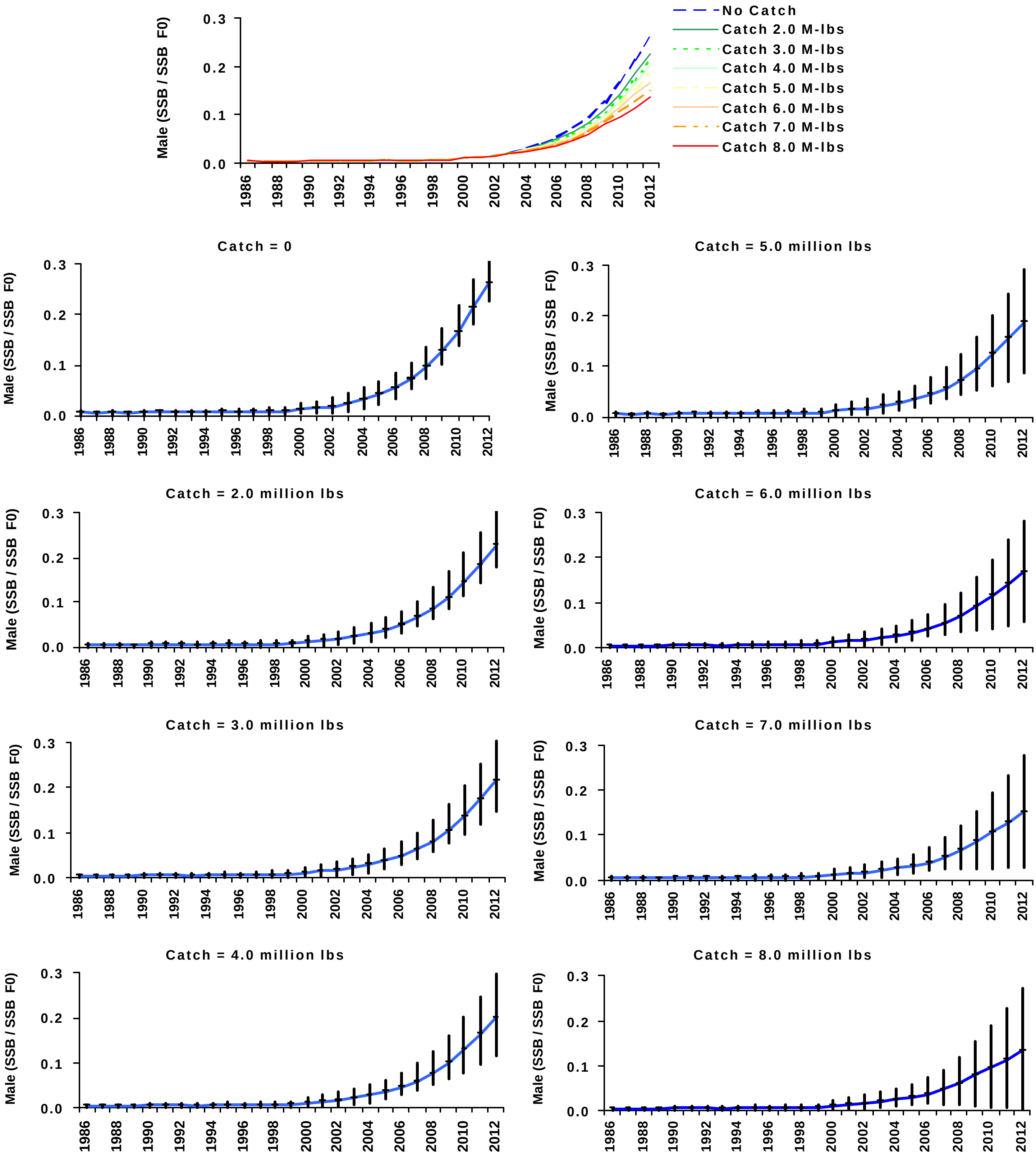



Figure 81. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA of the ALK+ catch-at-age with year-variable index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size.Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

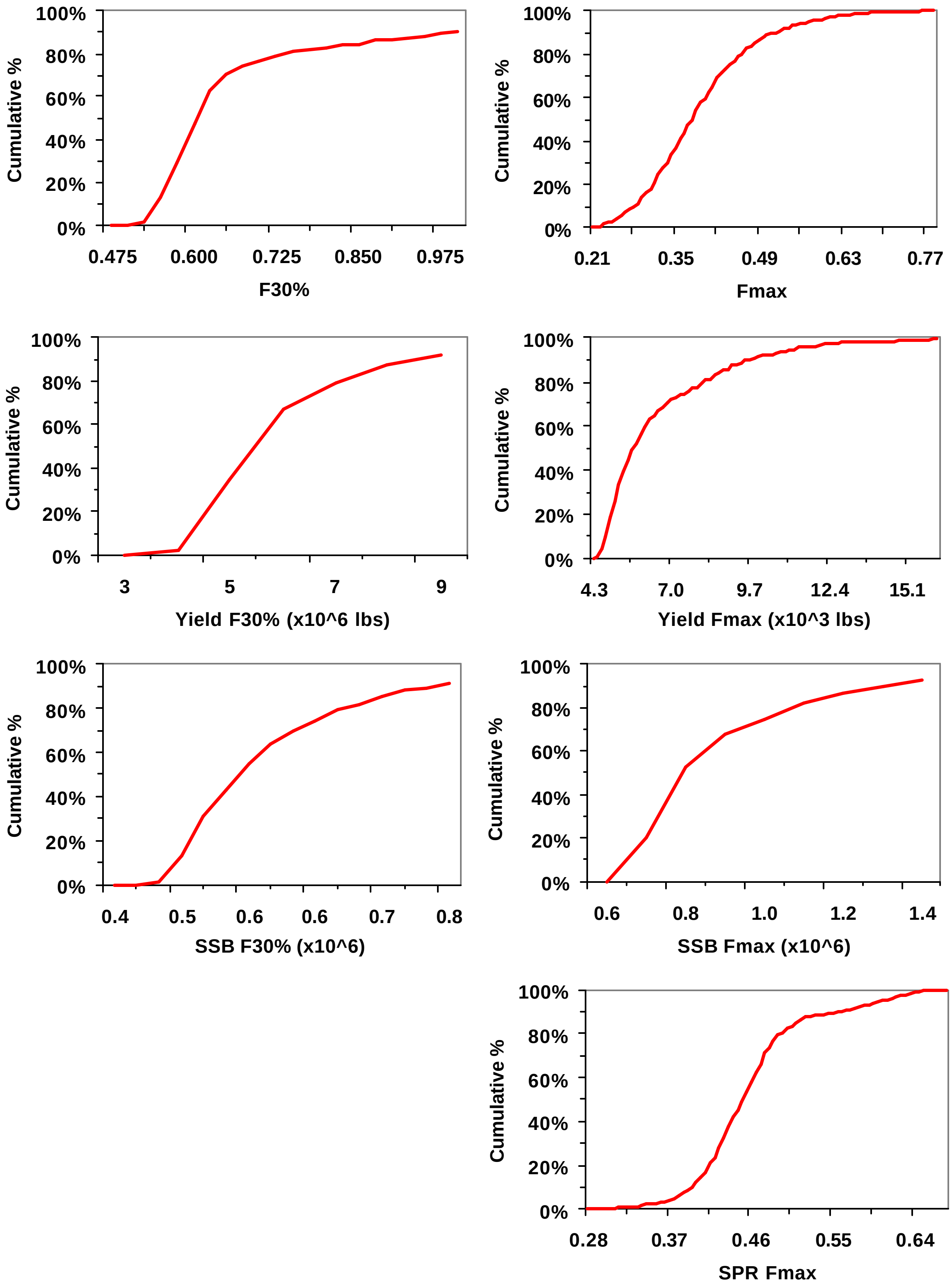



Figure 82. Cumulative frequency distributions for various reference statistics from bootstrapped estimates from the VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size.

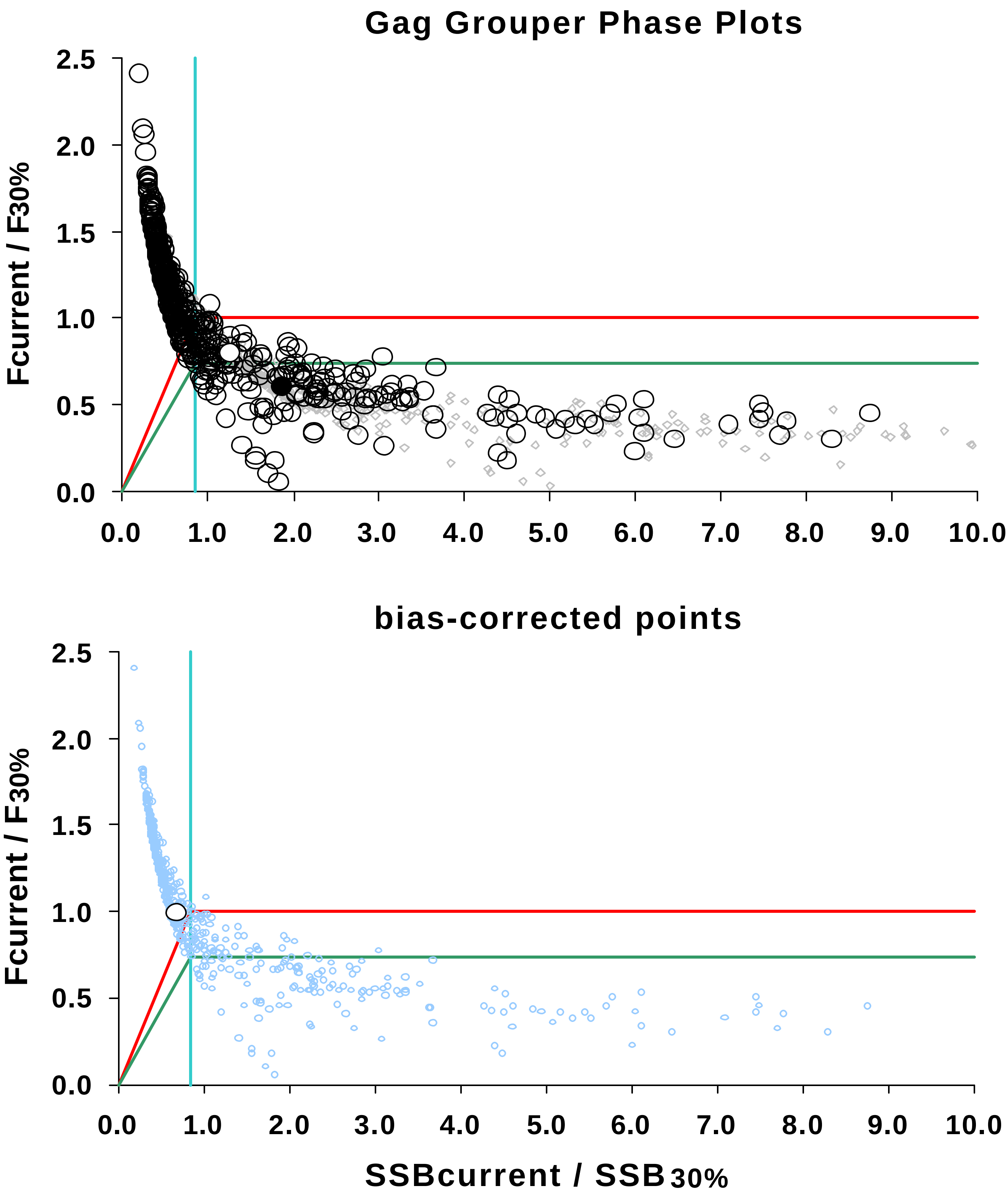



Figure 83. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to $SSB_{30\%}$ and $F_{30\%}$, respectively, from the VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

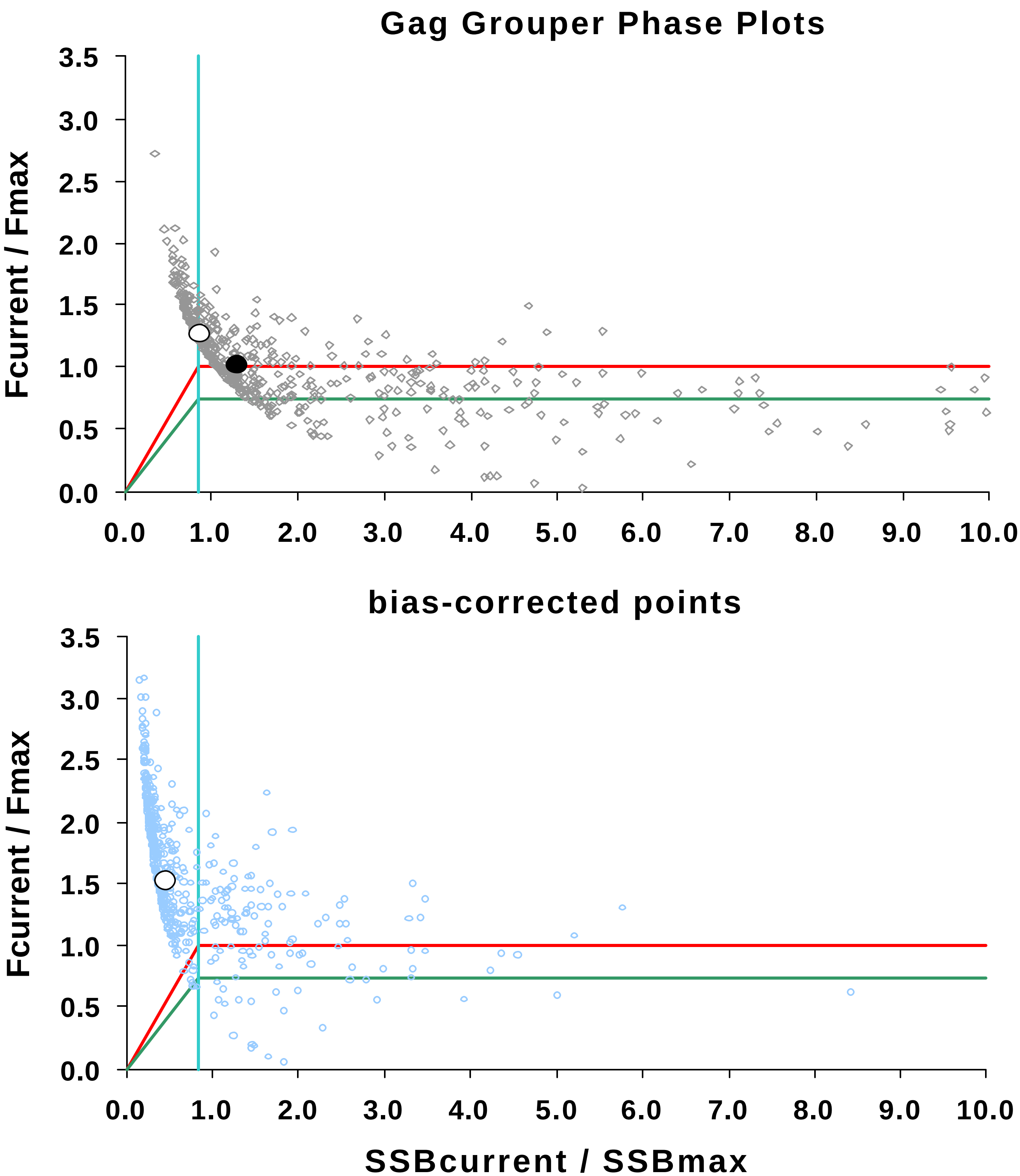



Figure 84. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to SSB and F at $F_{max}$ from the VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

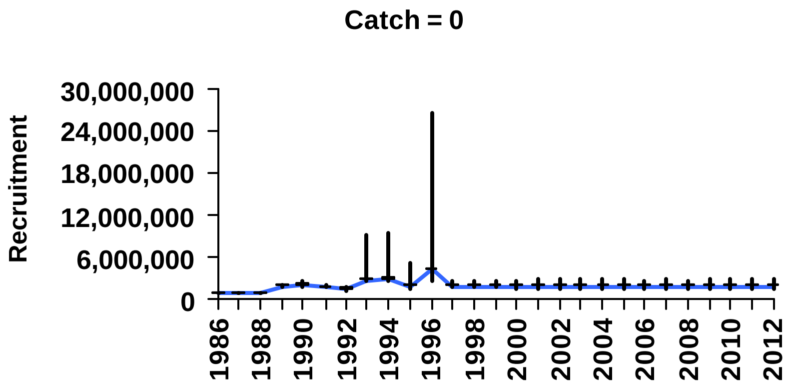



Figure 85. Historical and projected recruitment (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch after 2001.

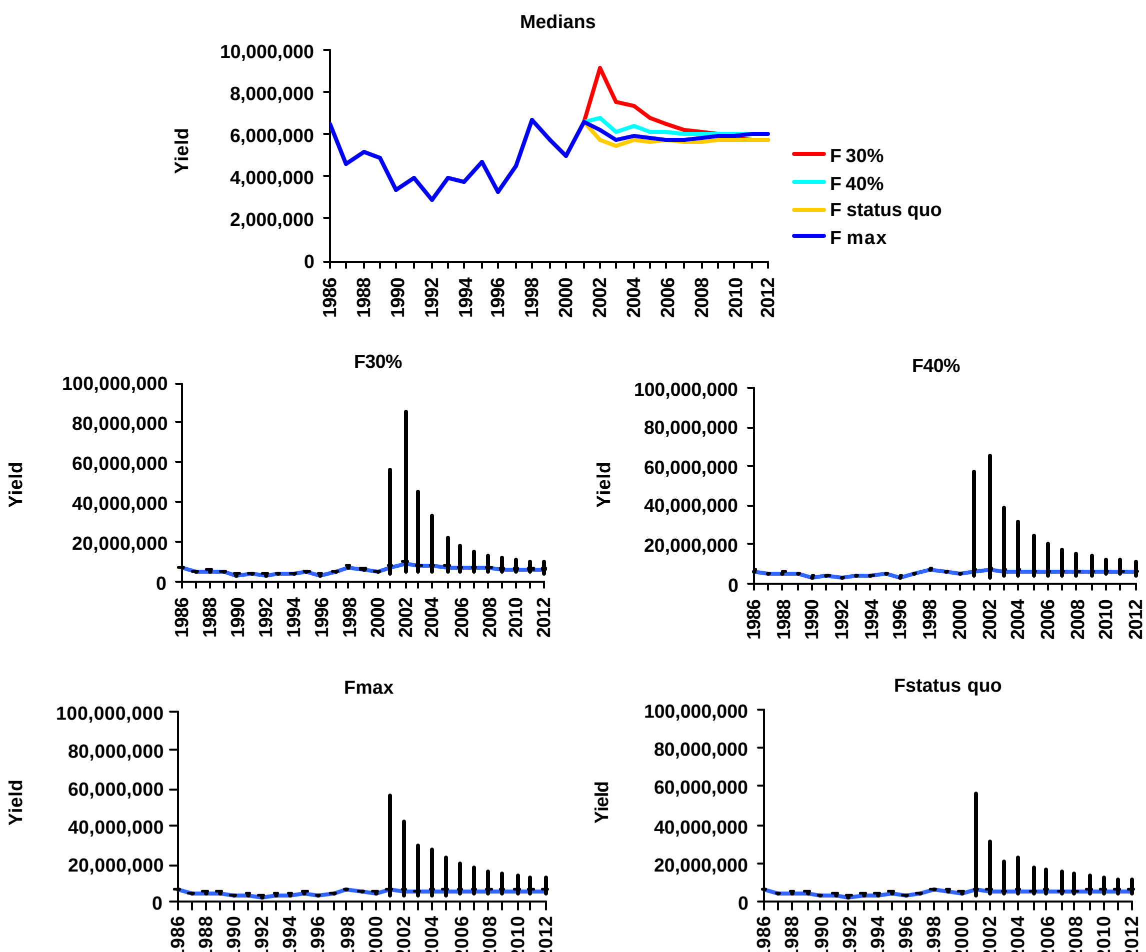



Figure 86. Historical and projected yield (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

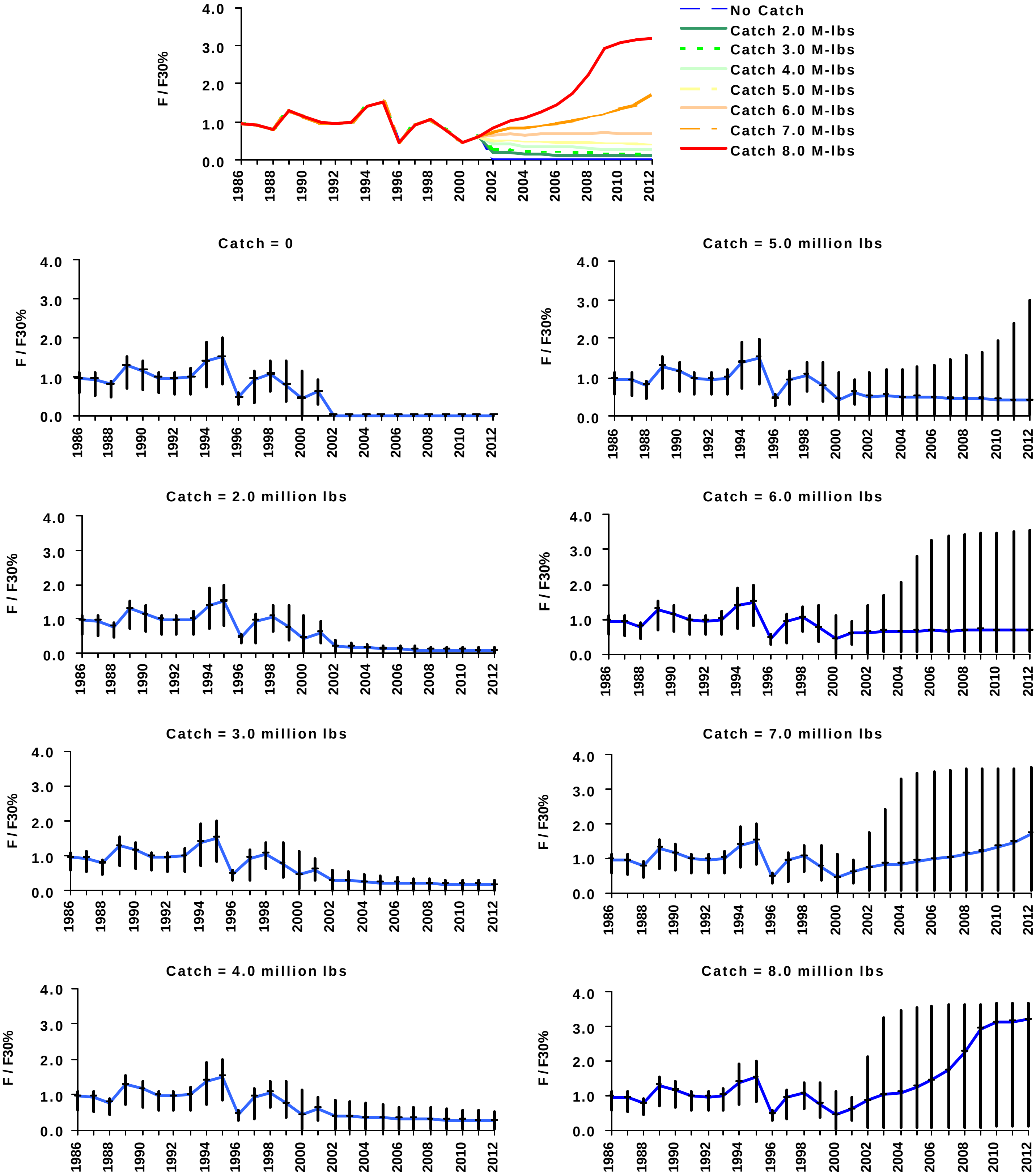



Figure 87. Historical and projected fishing mortality rate (F) relative to $F_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

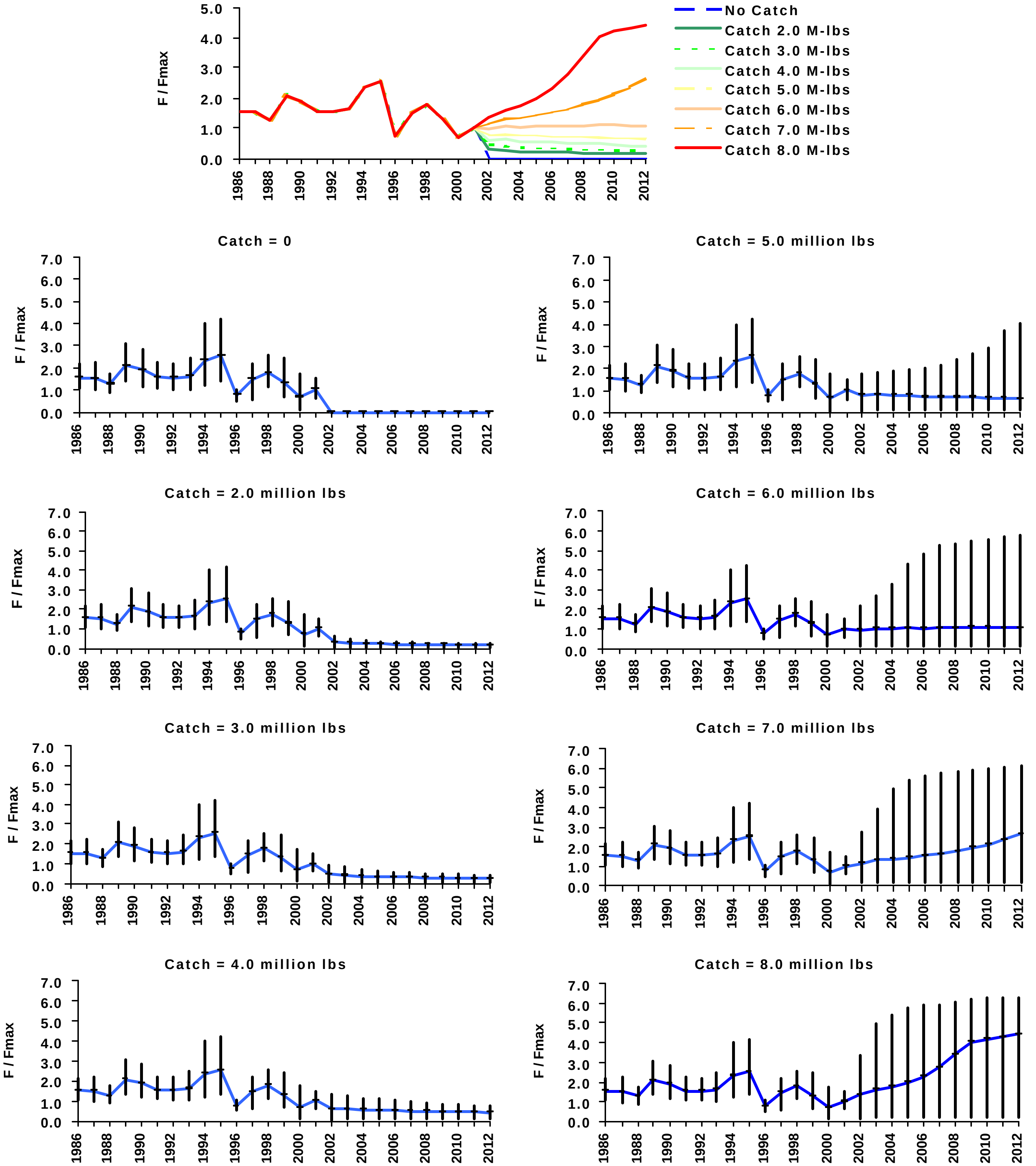



Figure 88. Historical and projected fishing mortality rate (F) relative to $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

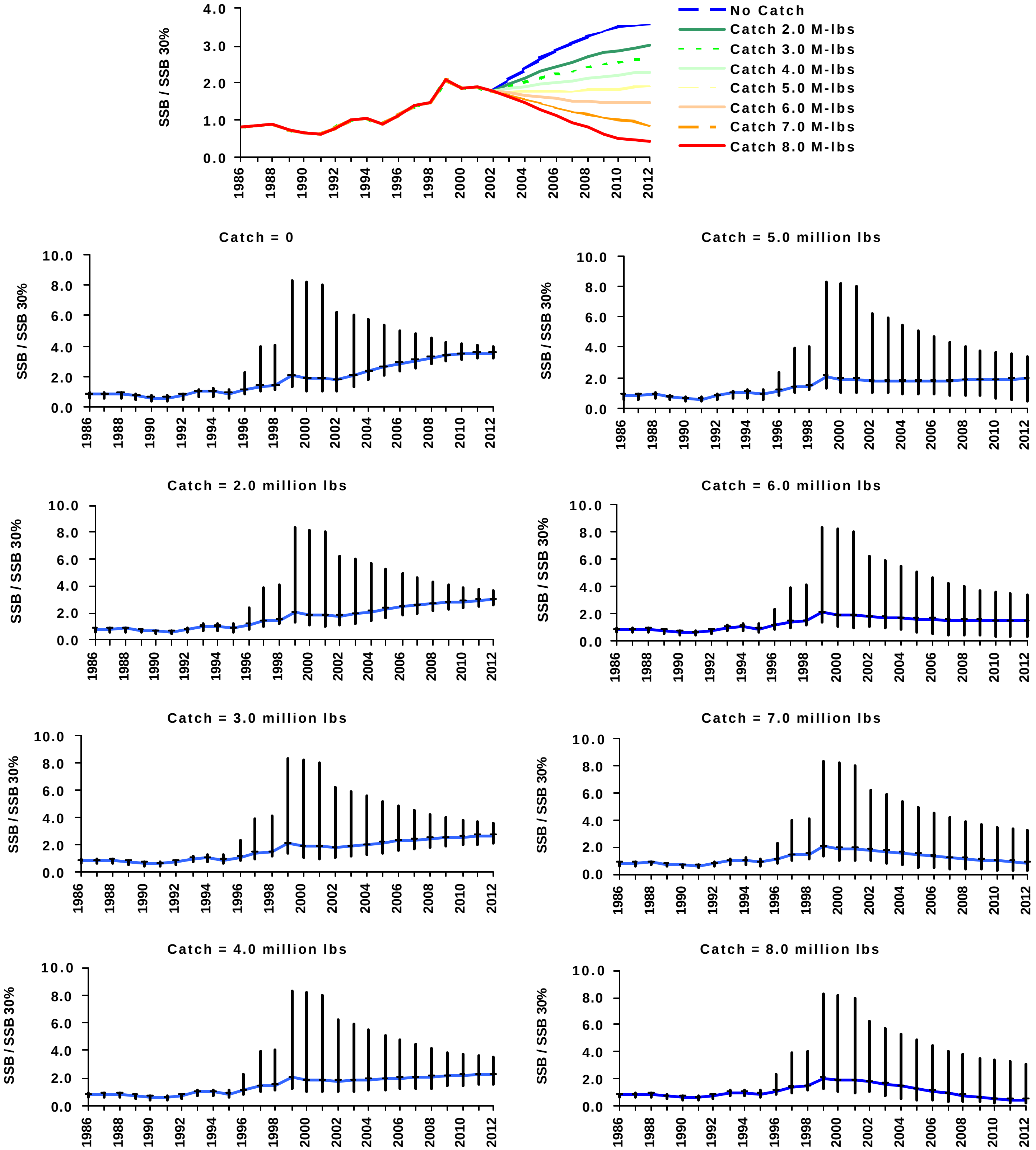



Figure 89. Historical and projected spawning stock biomass (SSB) relative to $SSB_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

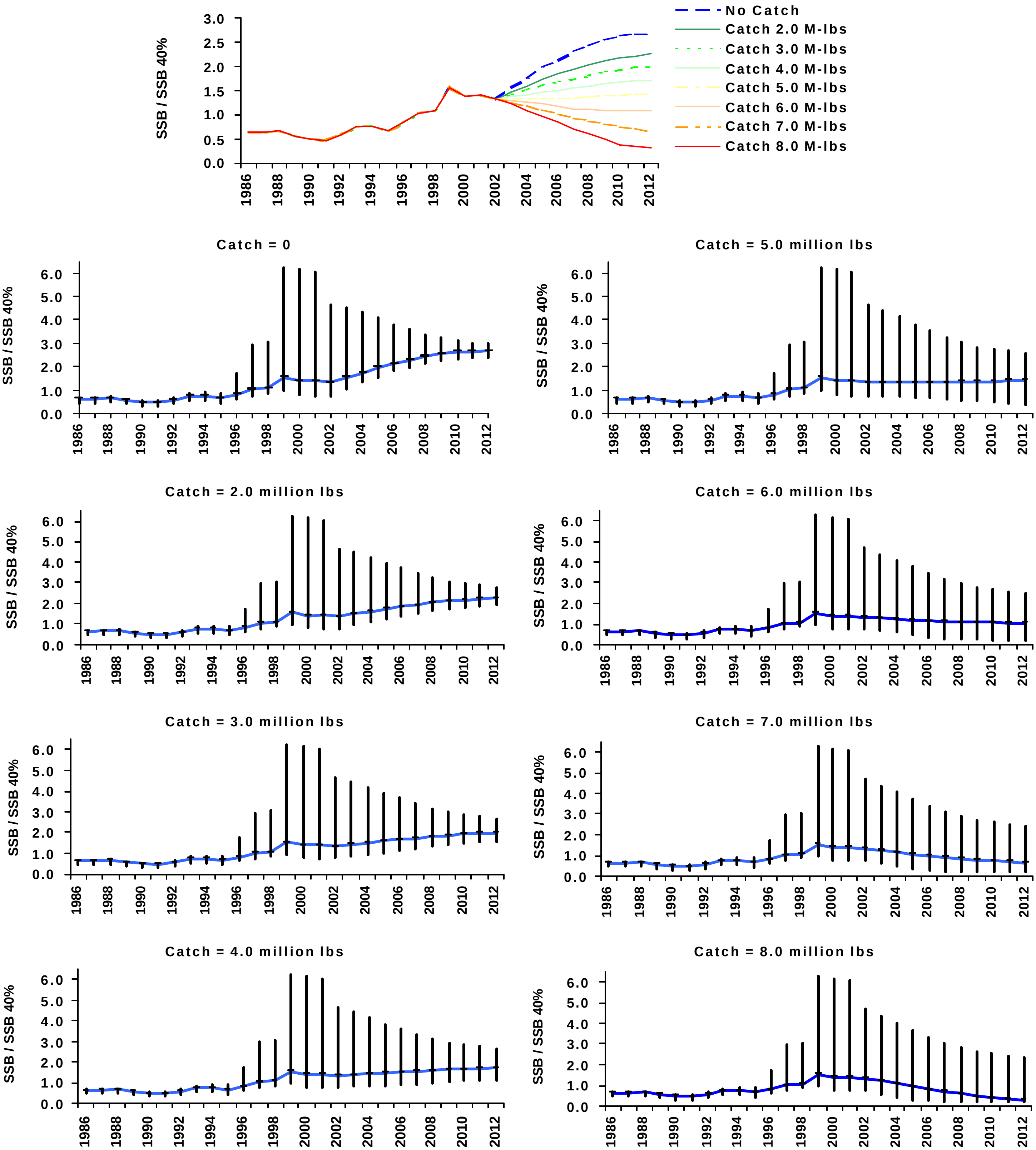



Figure 90. Historical and projected spawning stock biomass (SSB) relative to $SSB_{40\%}$ (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

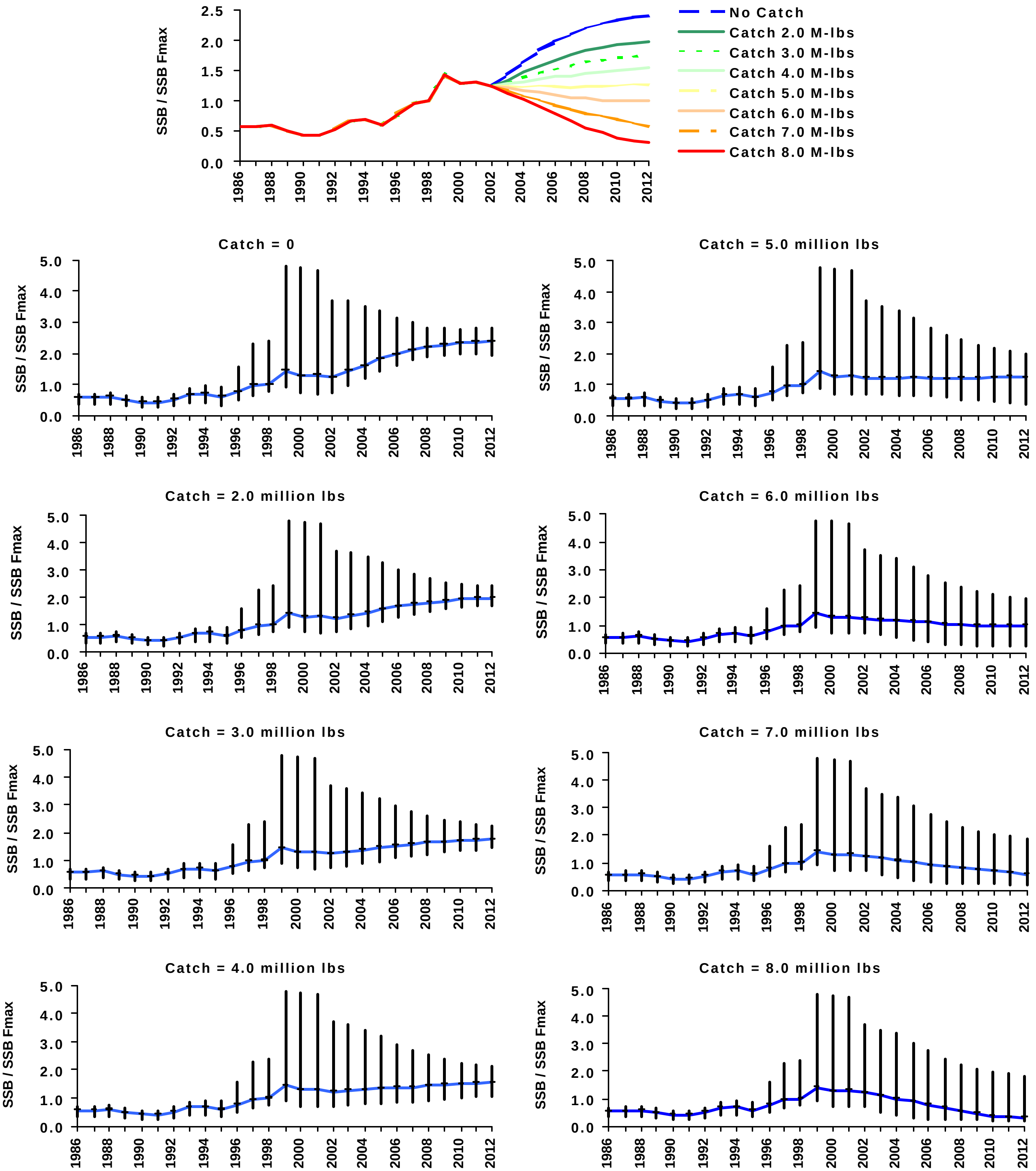



Figure 91. Historical and projected spawning stock biomass (SSB) relative to SSB at $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

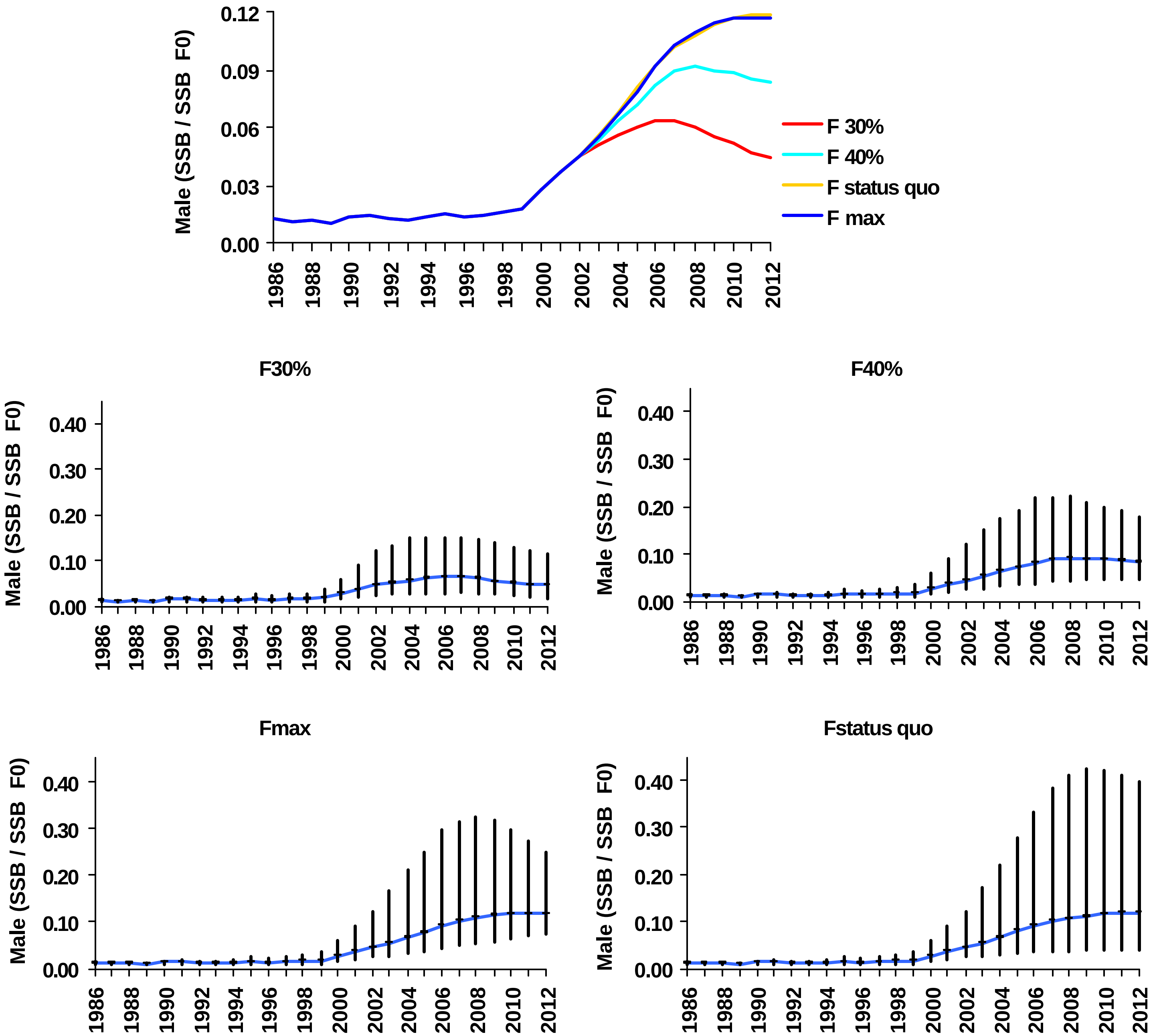



Figure 92. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

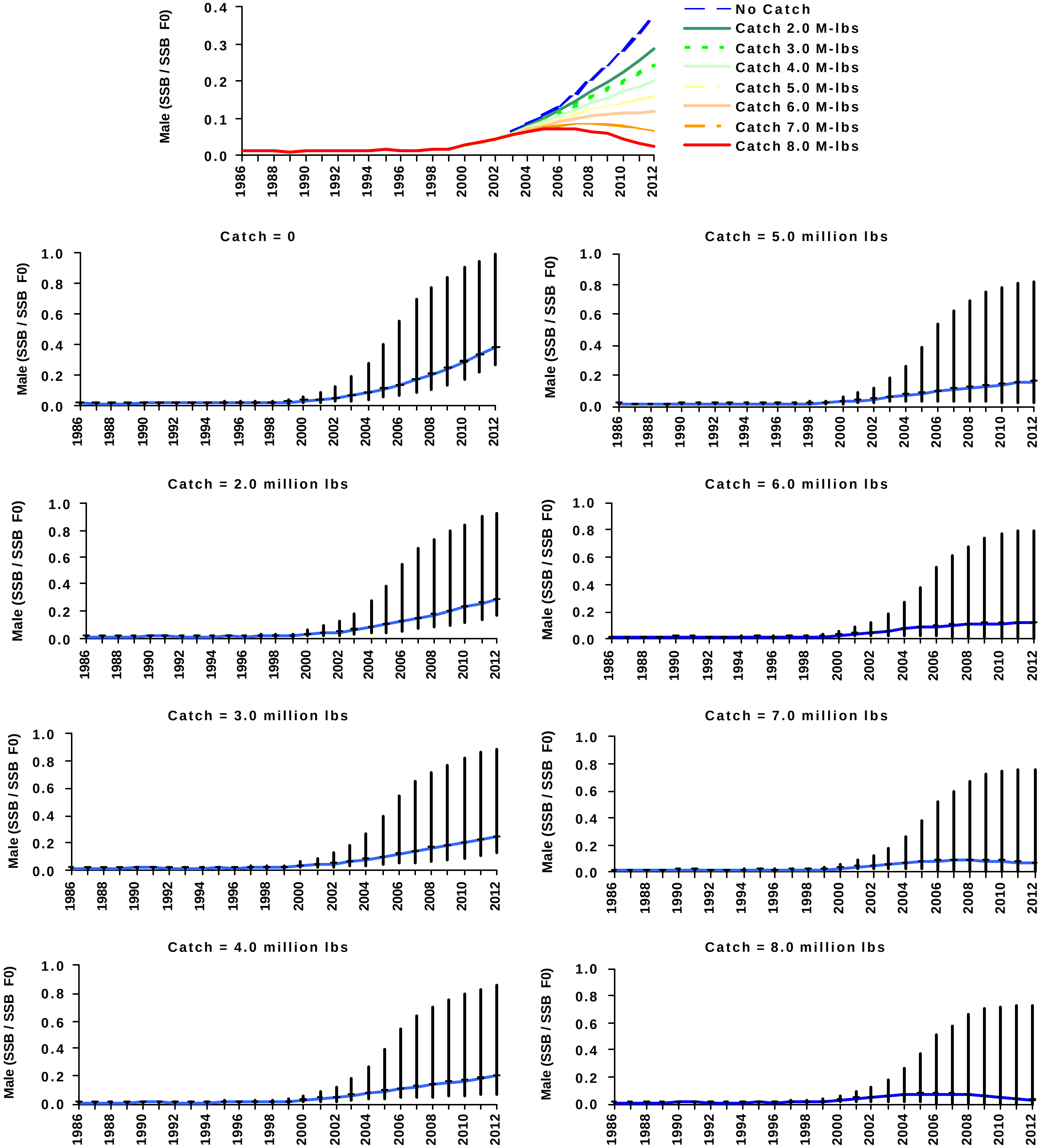



Figure 93. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped VPA using the ALK+ catch-at-age with year-variable index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

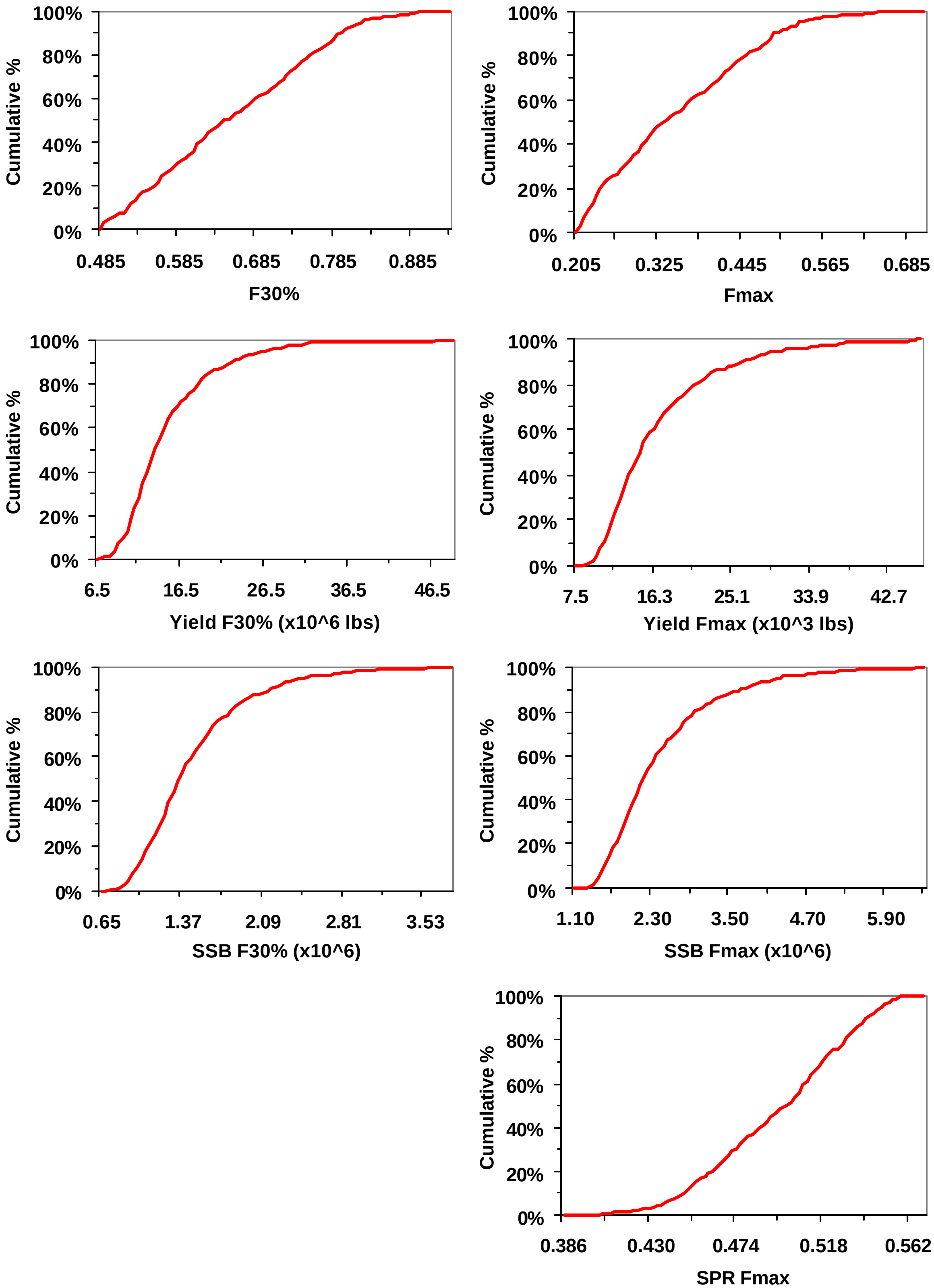



Figure 94. Cumulative frequency distributions for various reference statistics from bootstrapped estimates from the sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size.

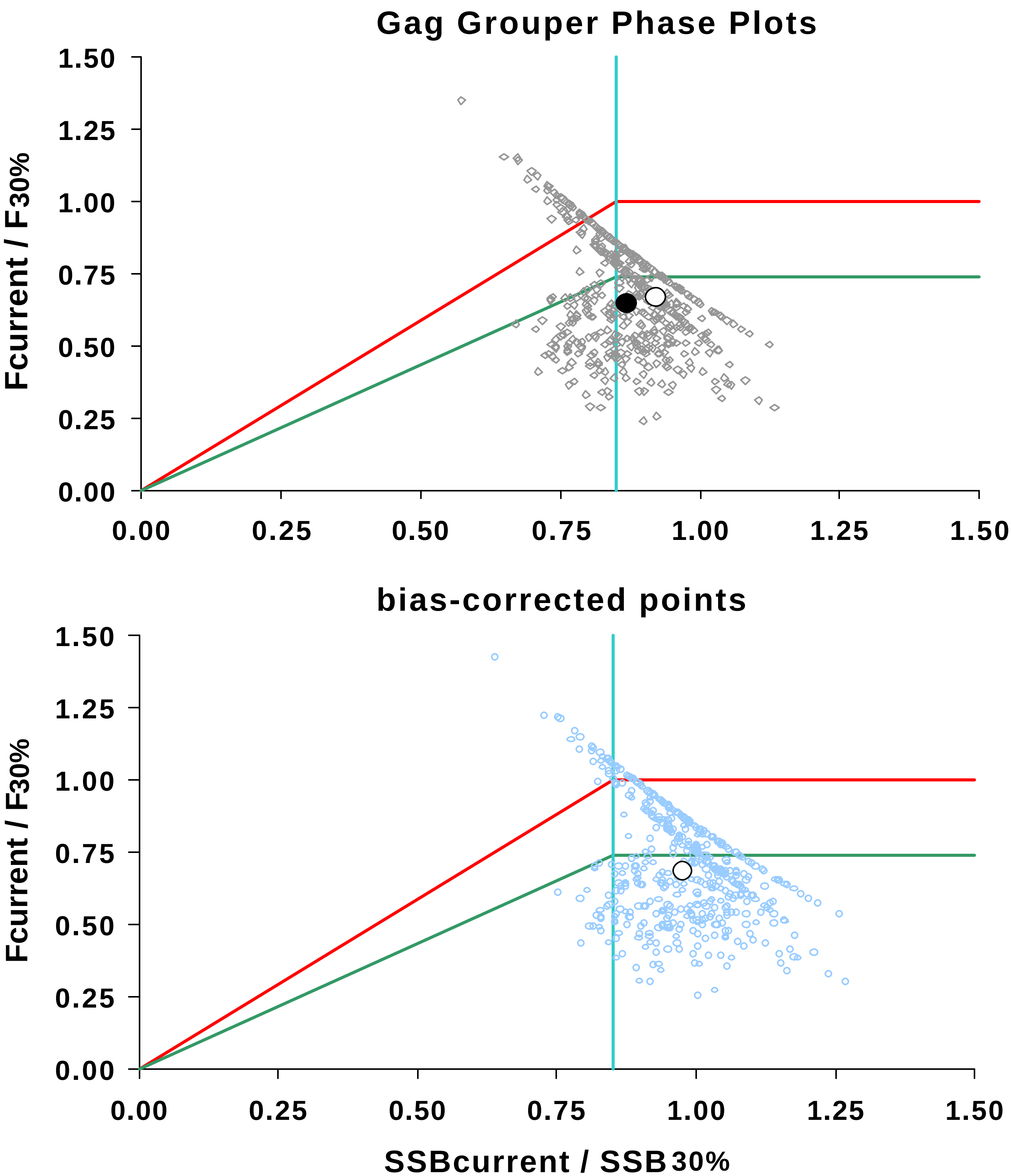



Figure 95. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to $SSB_{30\%}$ and $F_{30\%}$, respectively, from the sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

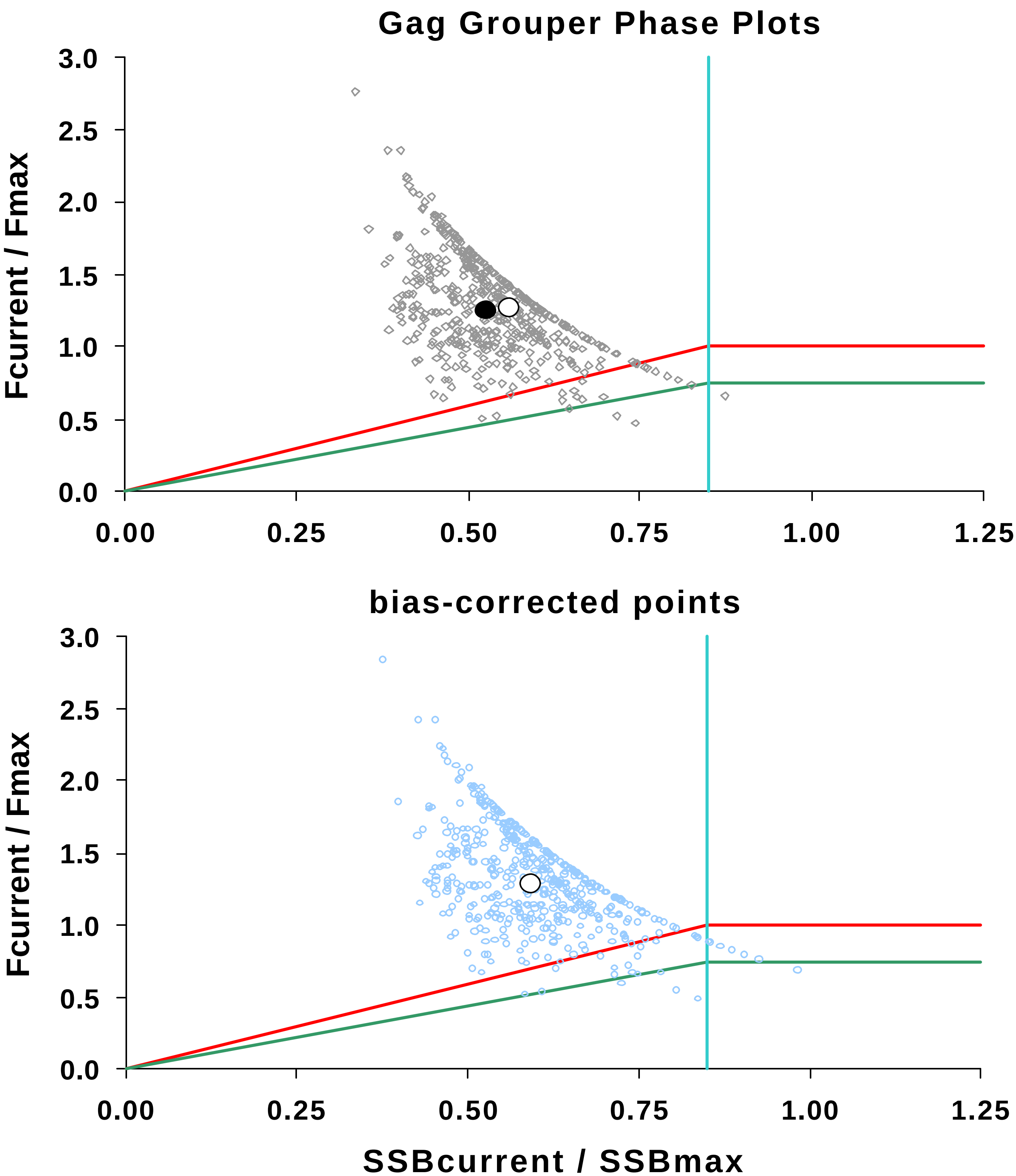



Figure 96. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to SSB and F at $F_{max}$ from the sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

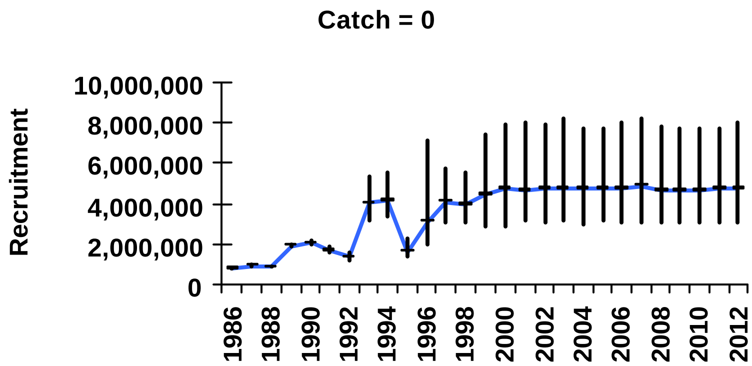



Figure 97. Historical and projected recruitment (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch after 2001.

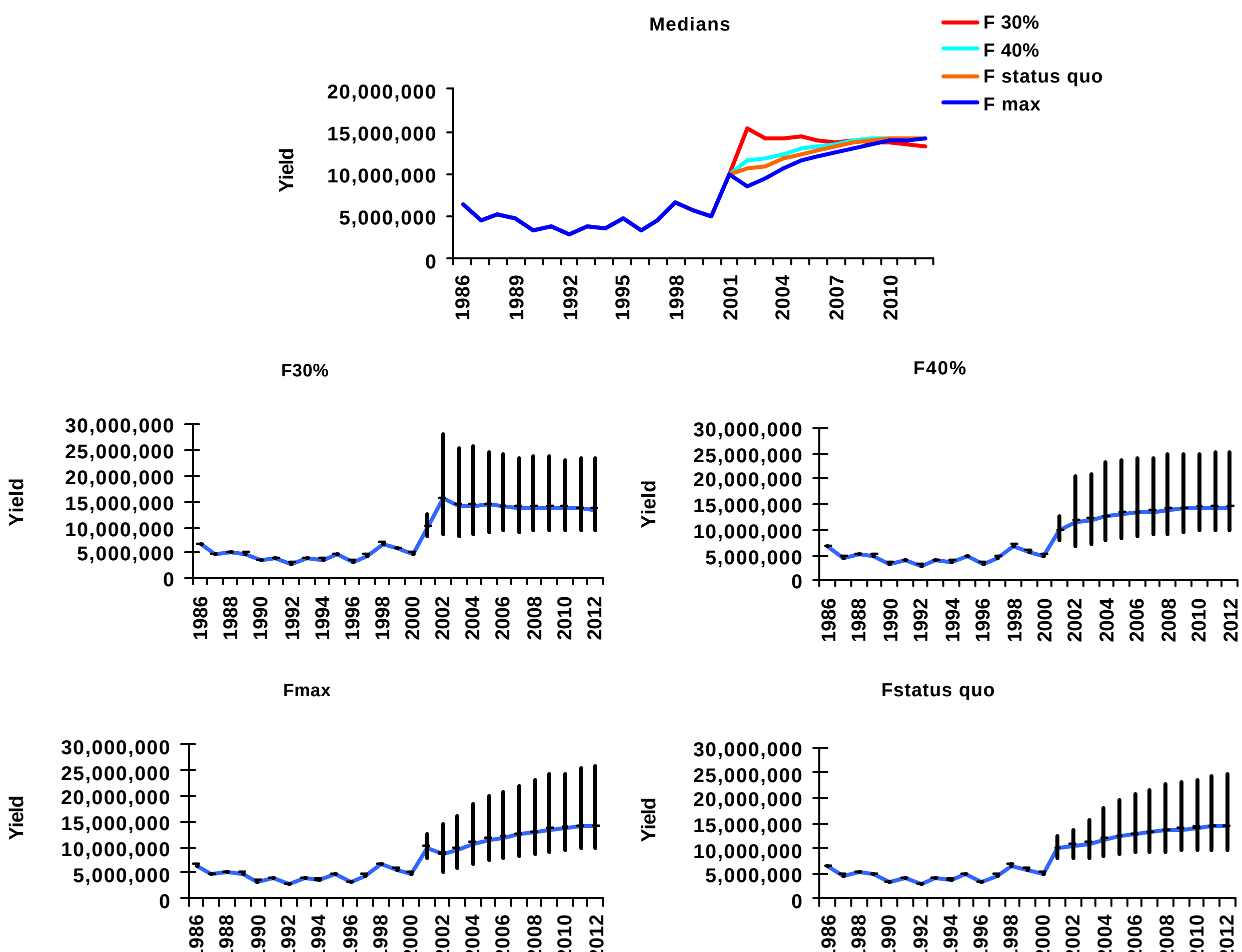



Figure 98. Historical and projected yield (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

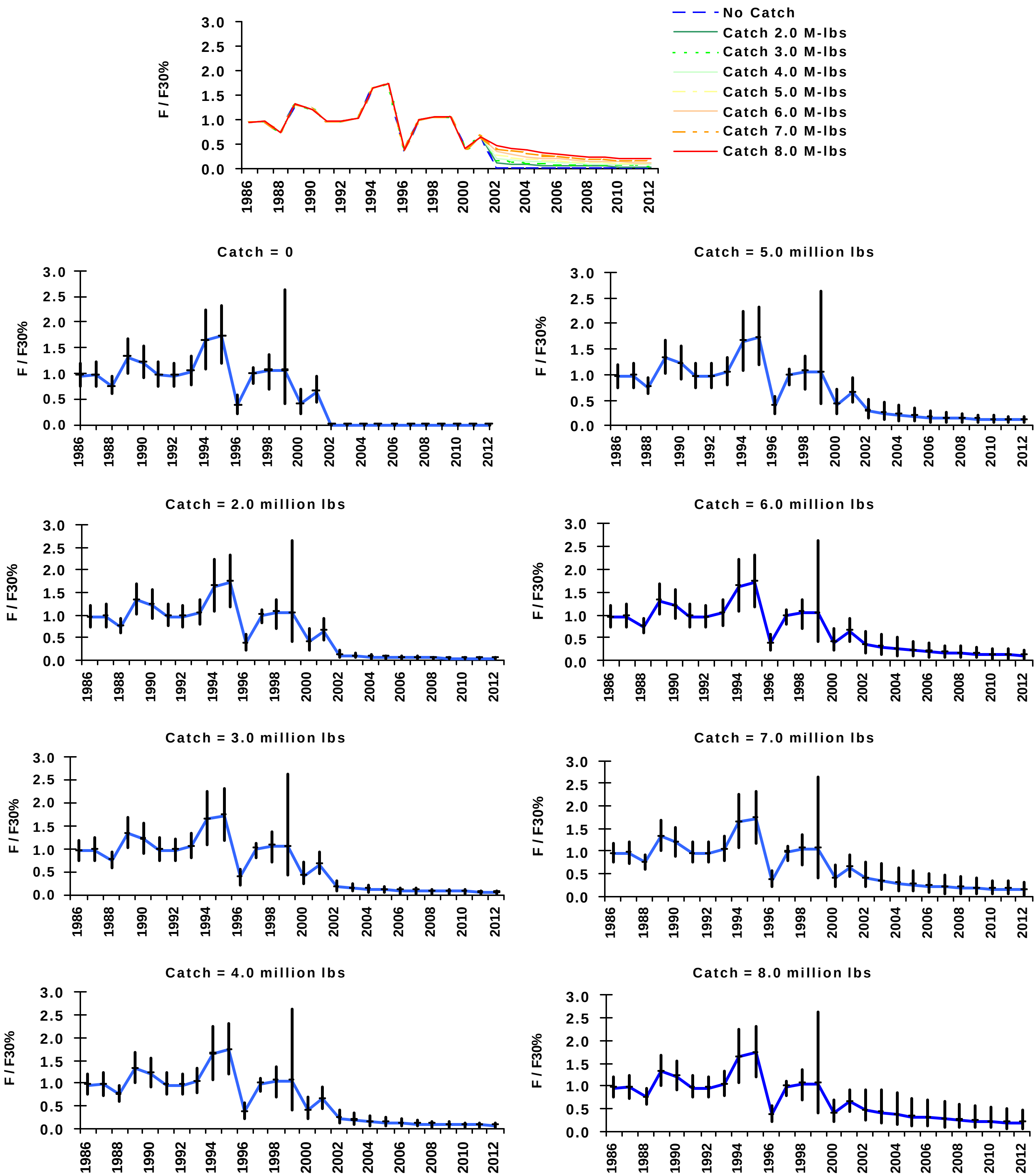



Figure 99. Historical and projected fishing mortality rate (F) relative to $F_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

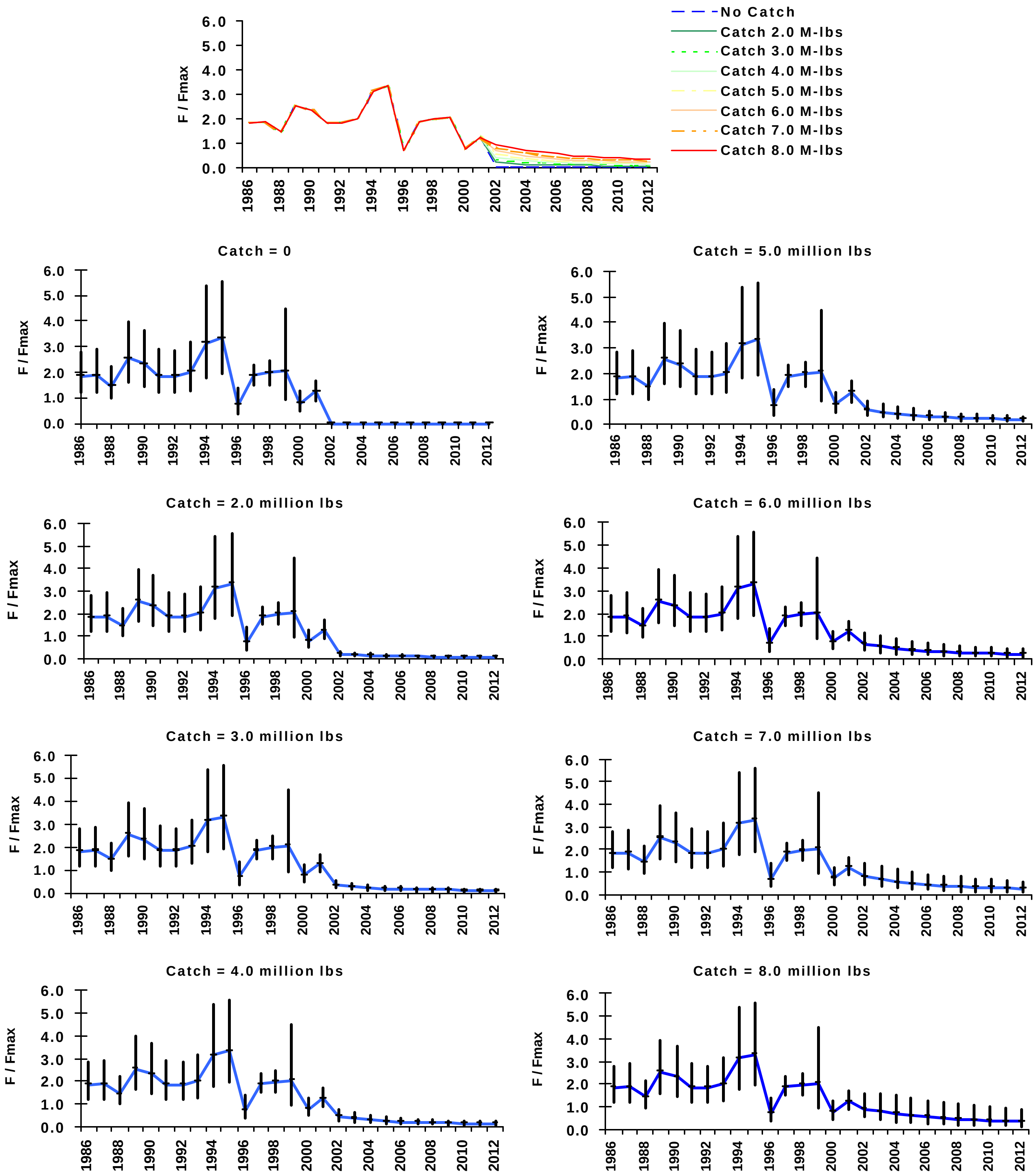



Figure 100. Historical and projected fishing mortality rate (F) relative to $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

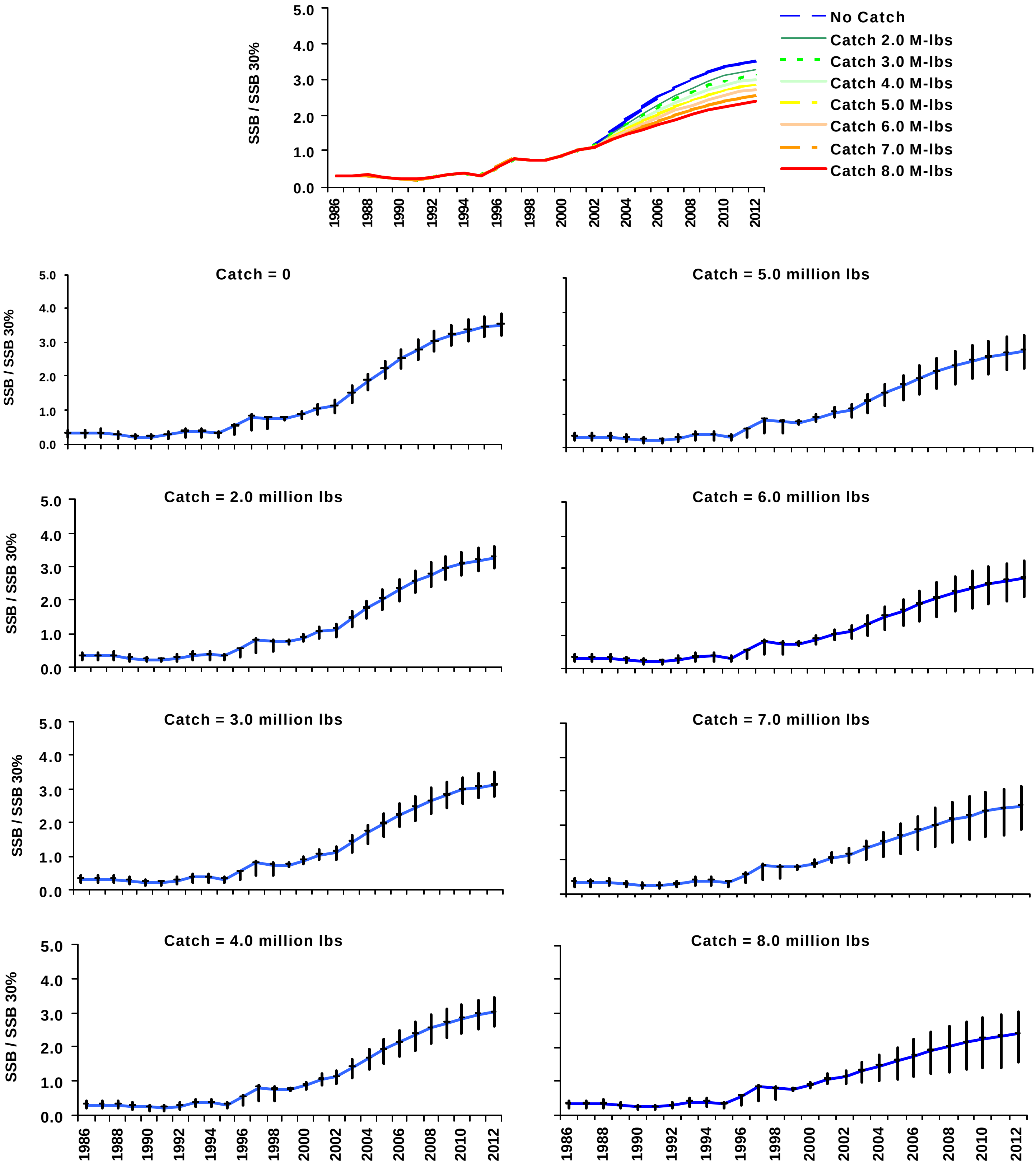



Figure 101. Historical and projected spawning stock biomass (SSB) relative to $SSB_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

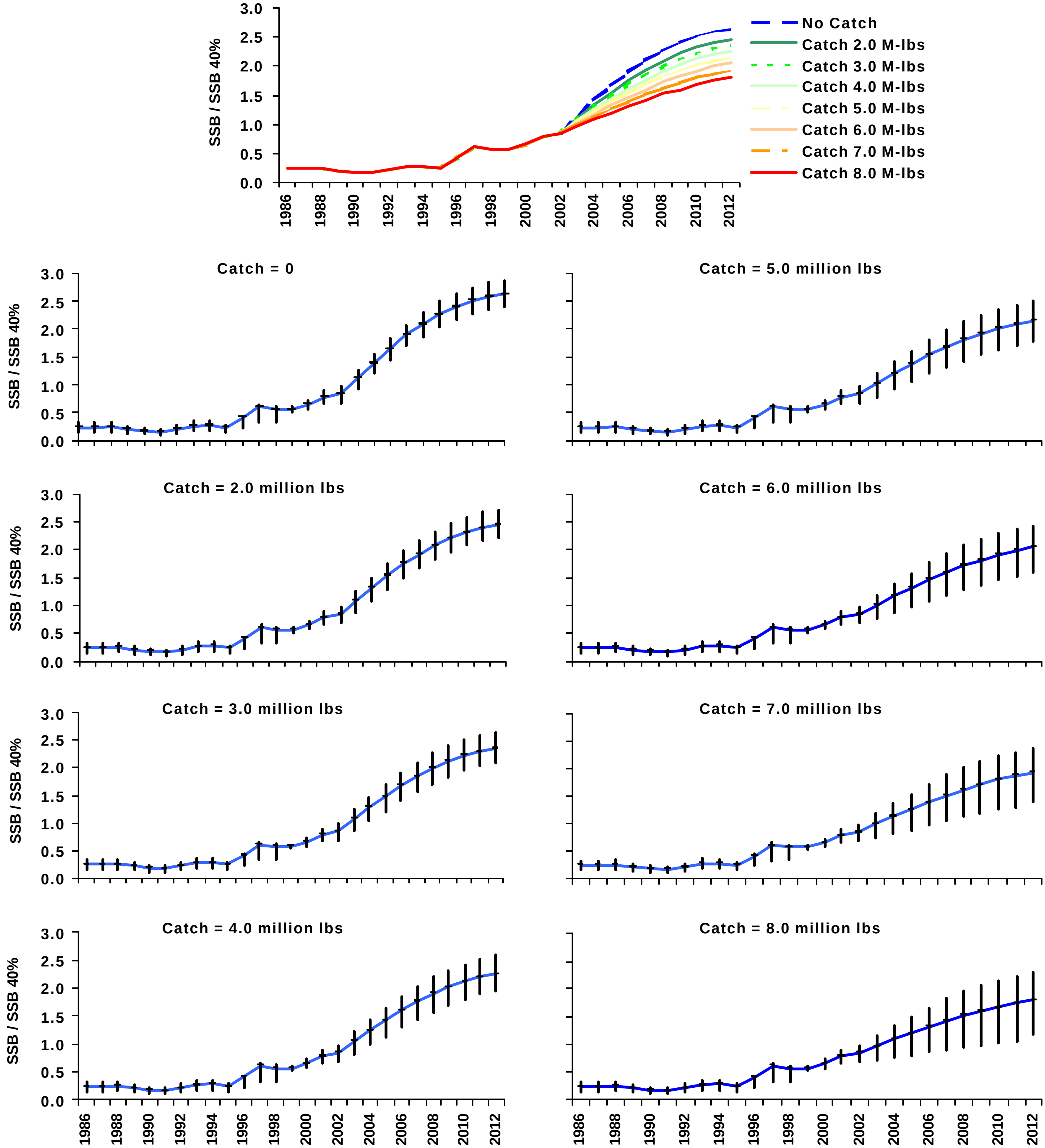



Figure 102. Historical and projected spawning stock biomass (SSB) relative to $SSB_{40\%}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

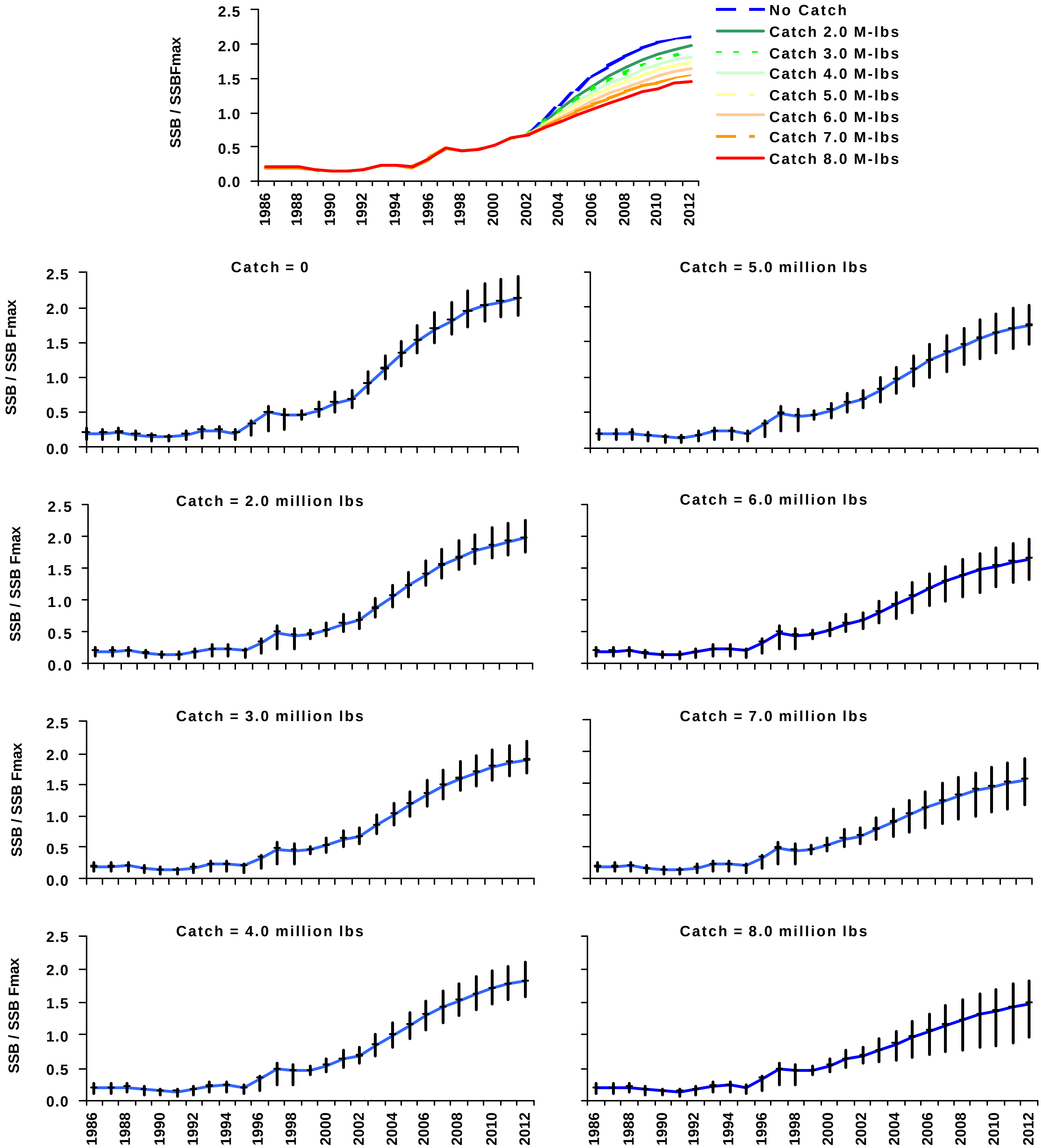



Figure 103. Historical and projected spawning stock biomass (SSB) relative to SSB at $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

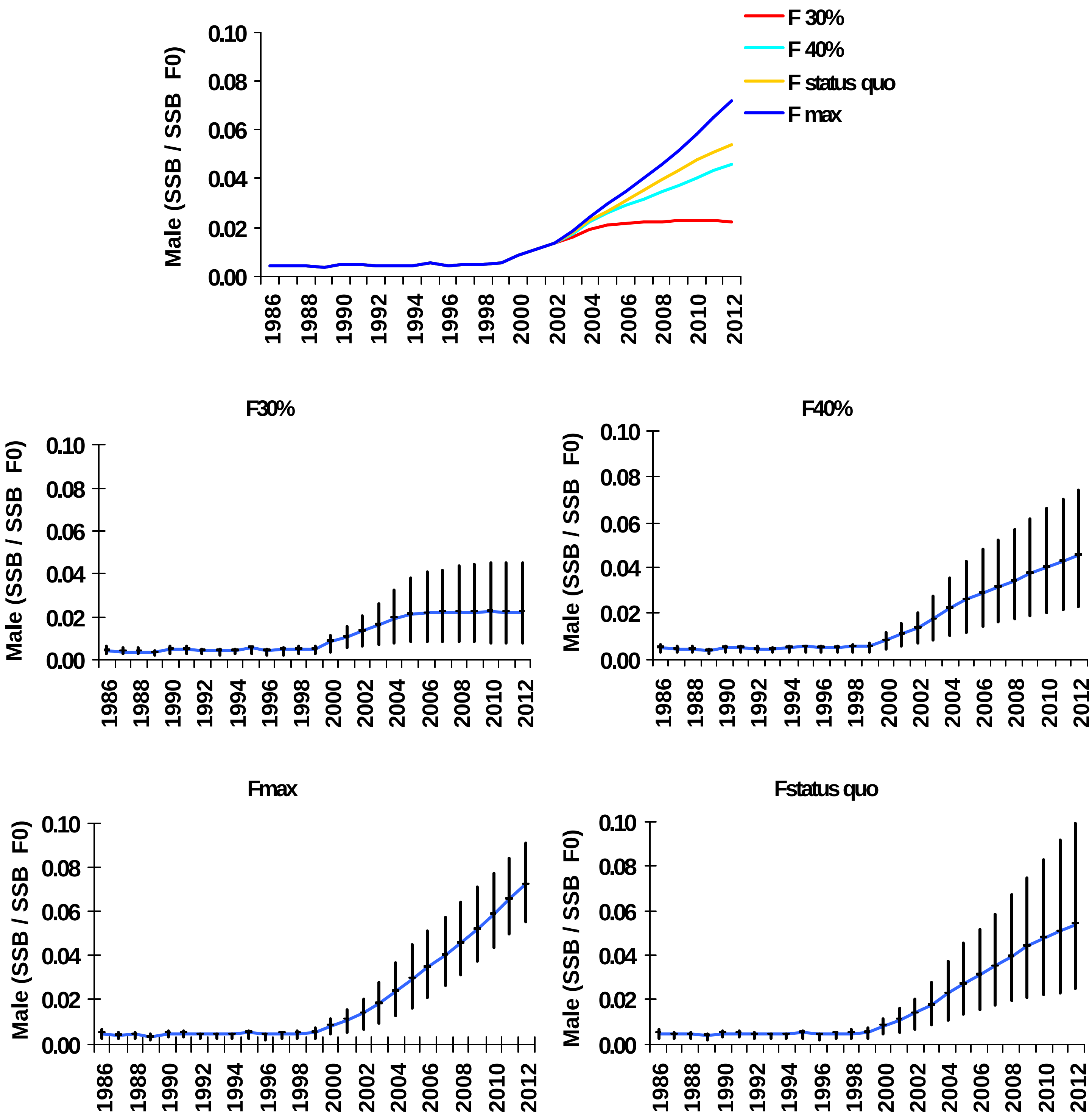



Figure 104. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

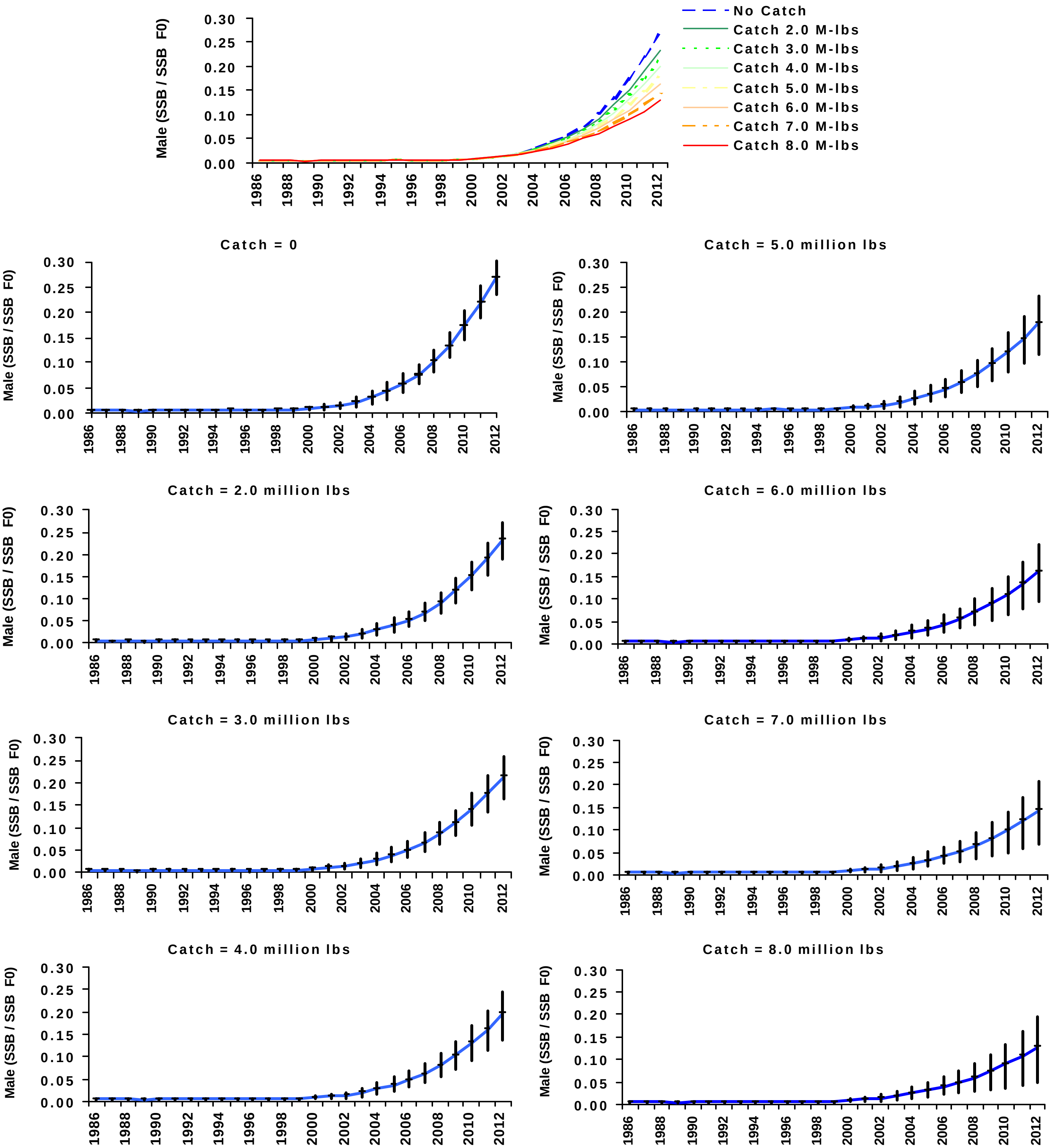



Figure 105. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and recruitment increasing to the maximum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

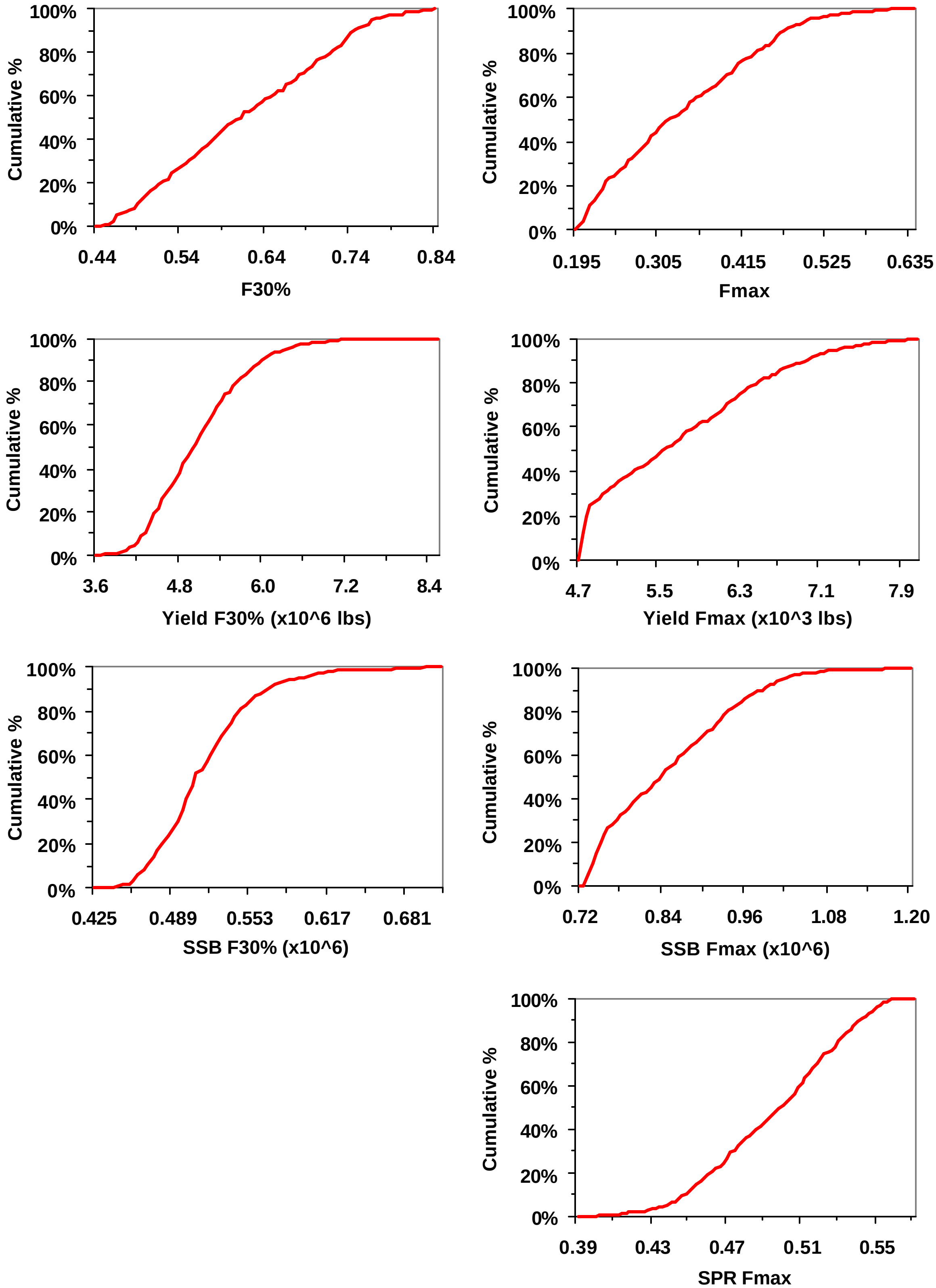



Figure 106. Cumulative frequency distributions for various reference statistics from bootstrapped estimates from the sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size.

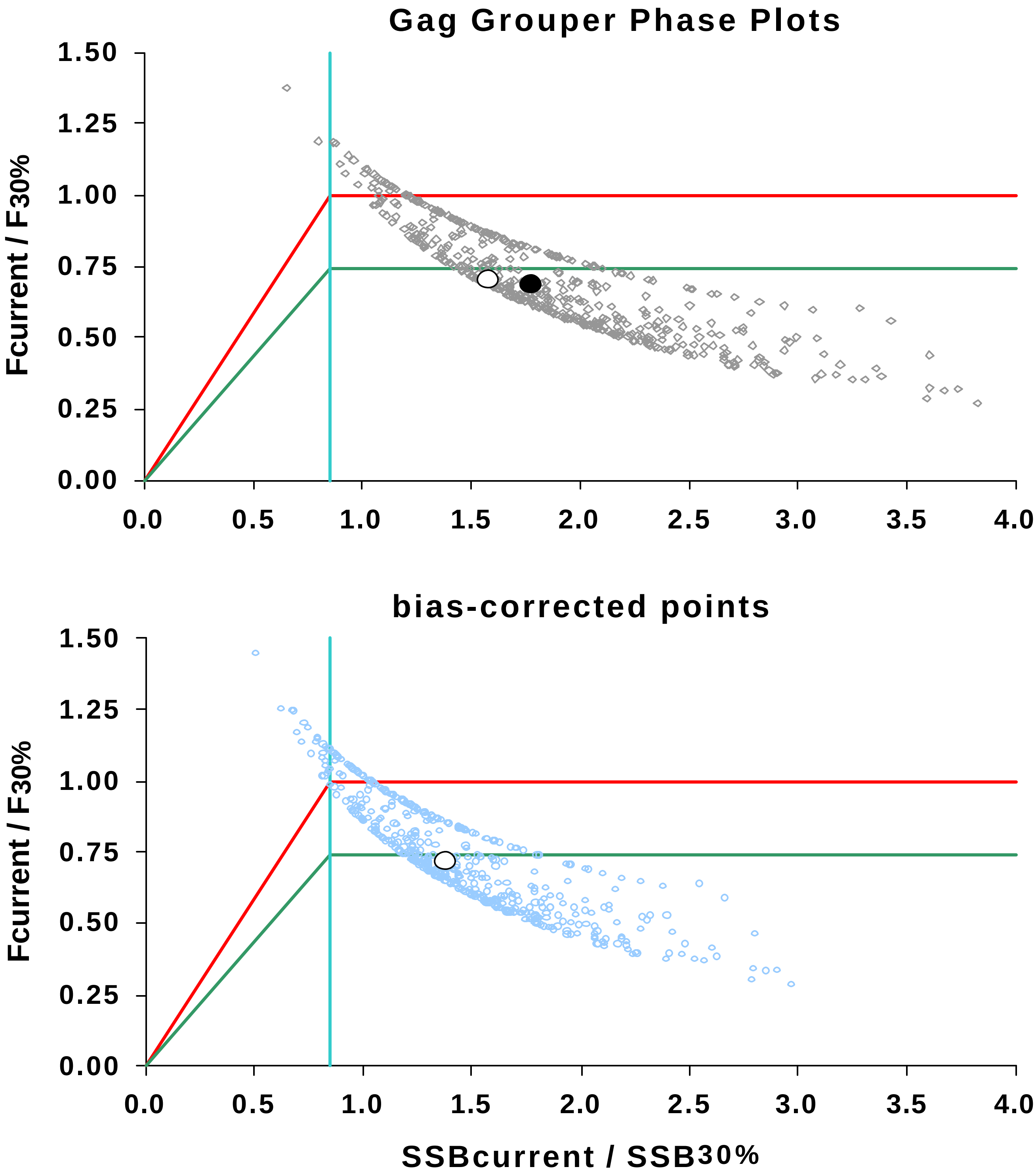



Figure 107. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to $SSB_{30\%}$ and $F_{30\%}$, respectively, from the sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

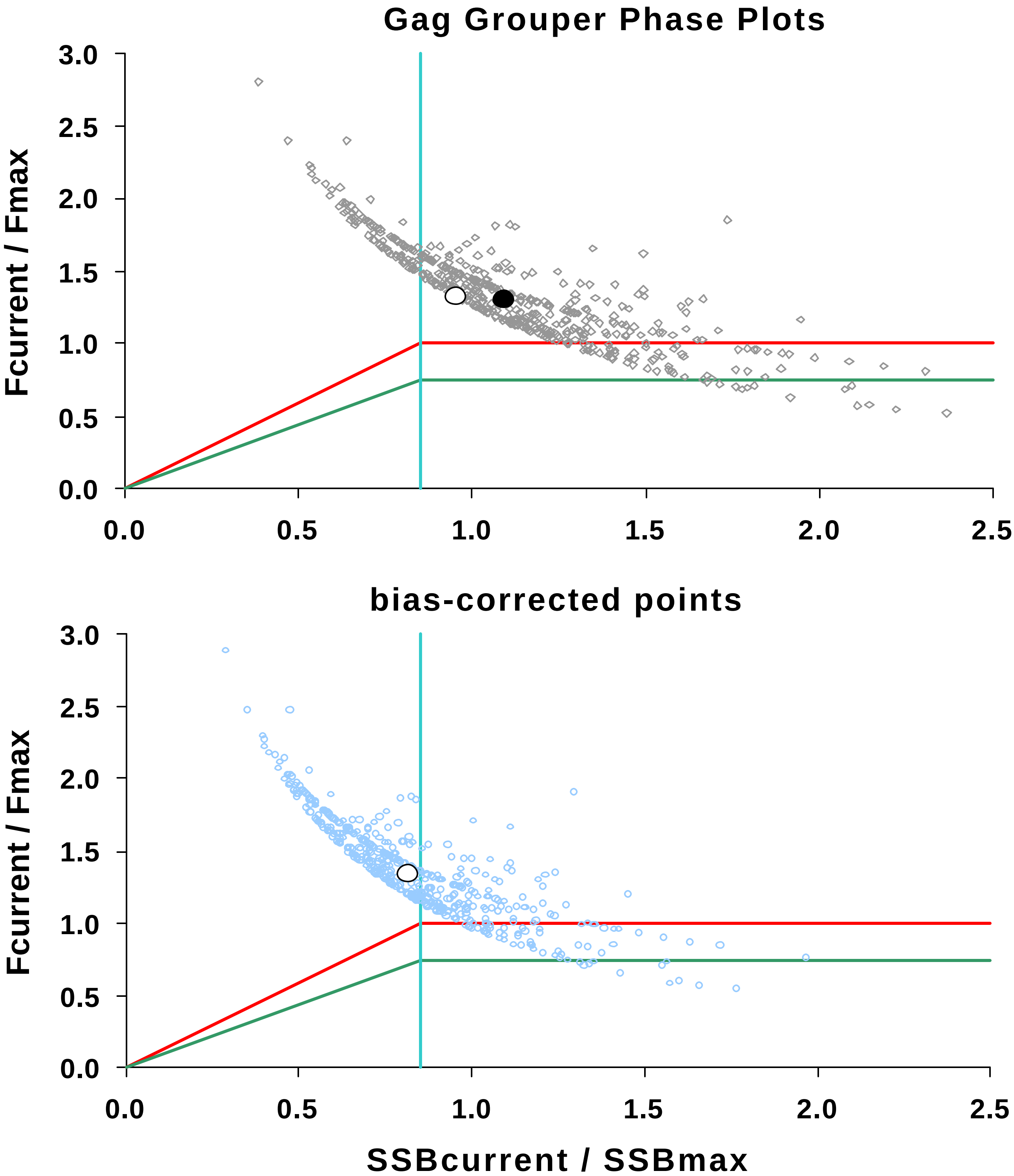



Figure 108. Individual bootstrap estimates of spawning stock biomass (SSB) and fishing mortality rate (F) relative to SSB and F at $F_{max}$ from the sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. The upper panel shows uncorrected results, with the median of the bootstraps (black oval) and the deterministic estimate (white oval). The lower panel shows the bias corrected individual bootstrap and deterministic estimates.

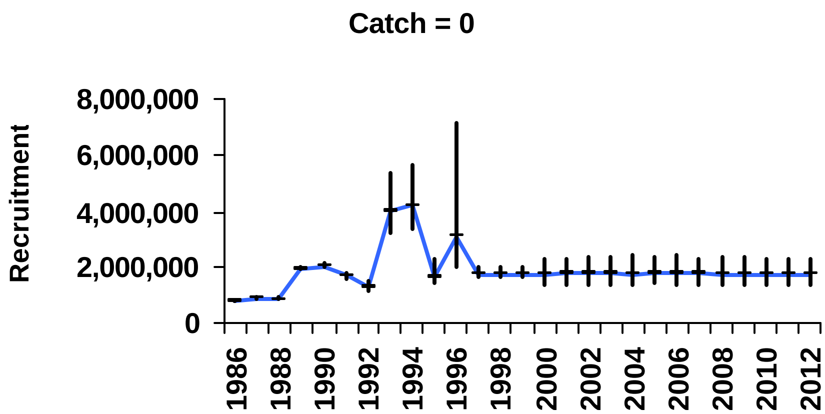



Figure 109. Historical and projected recruitment (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch after 2001.

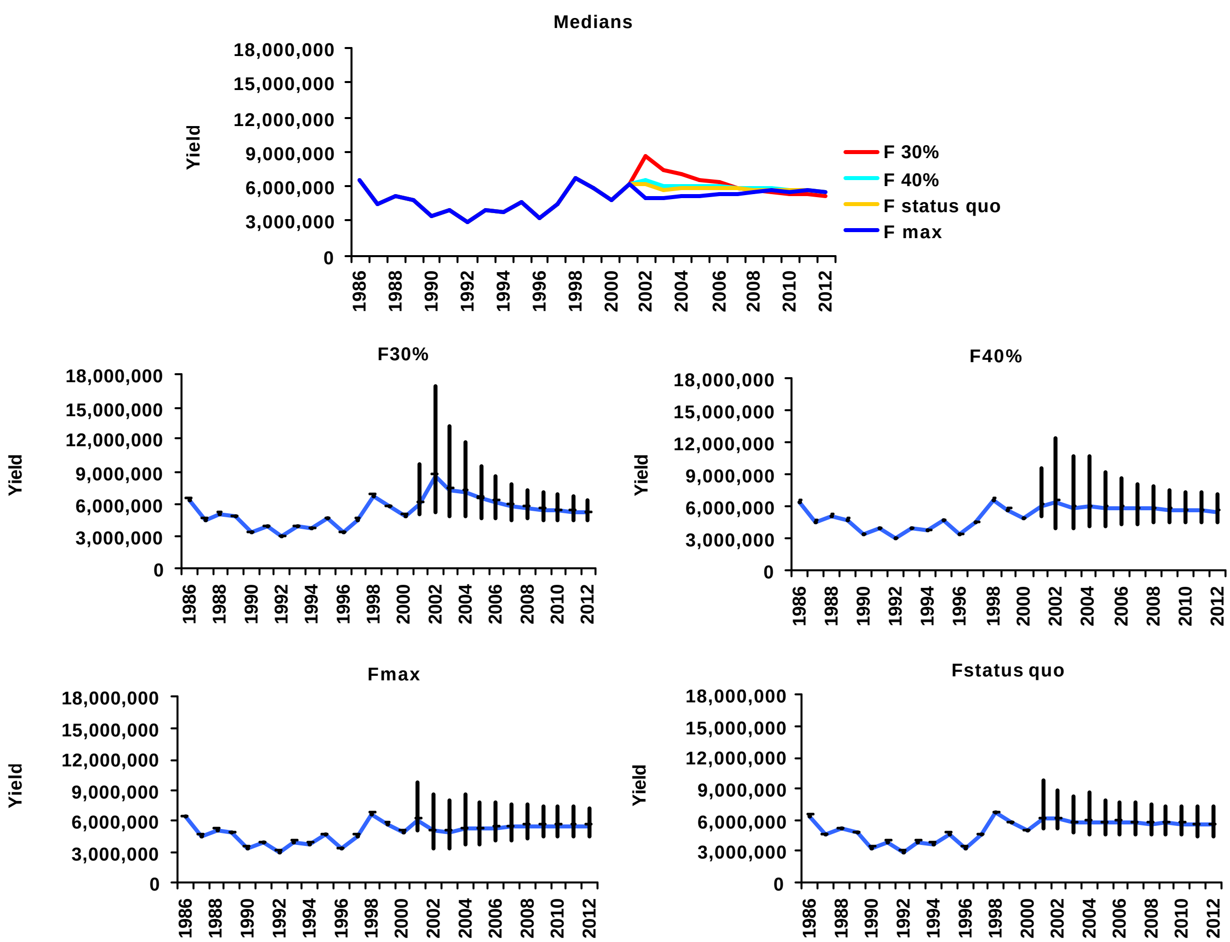



Figure 110. Historical and projected yield (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

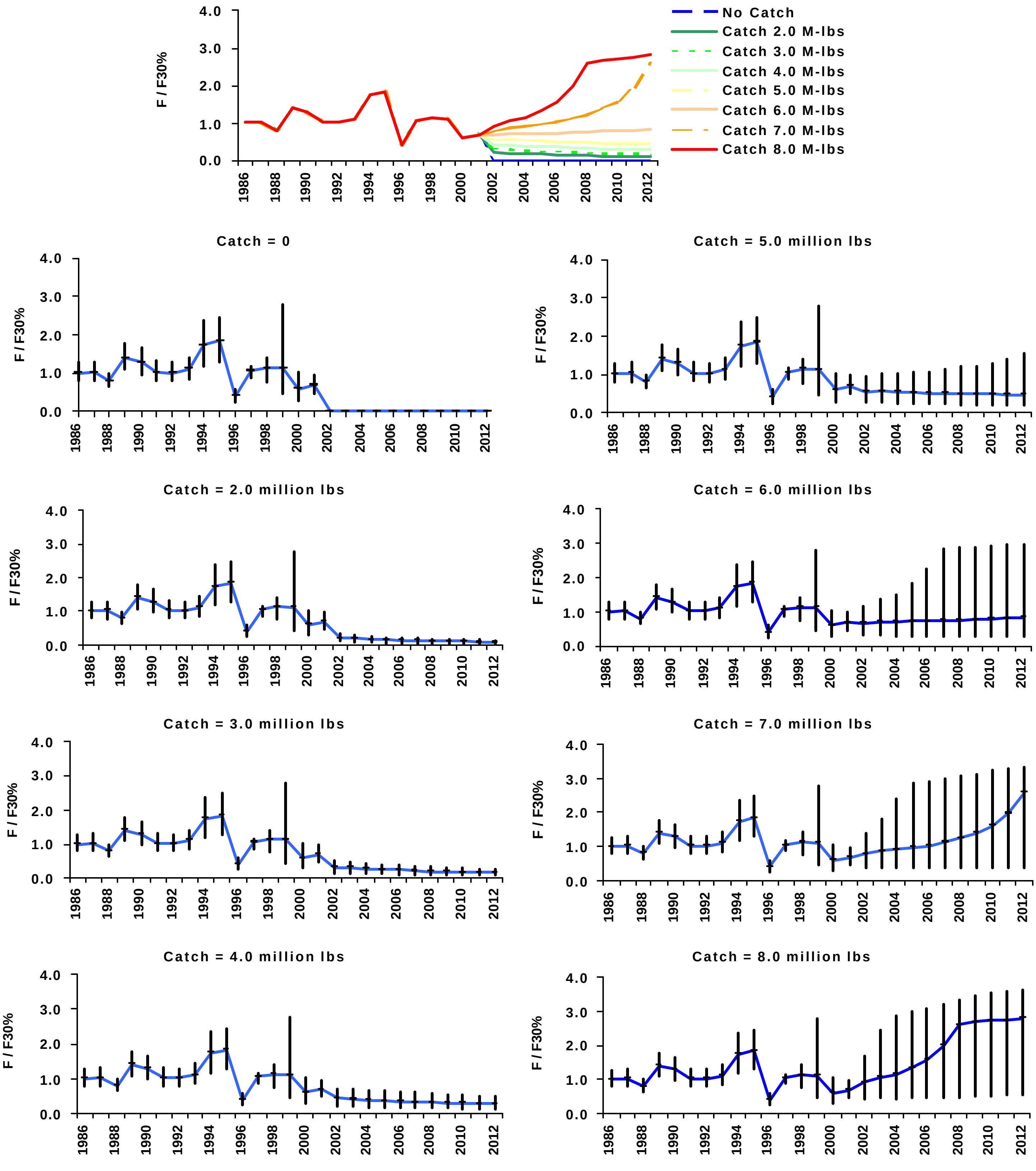



Figure 111. Historical and projected fishing mortality rate (F) relative to $F_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

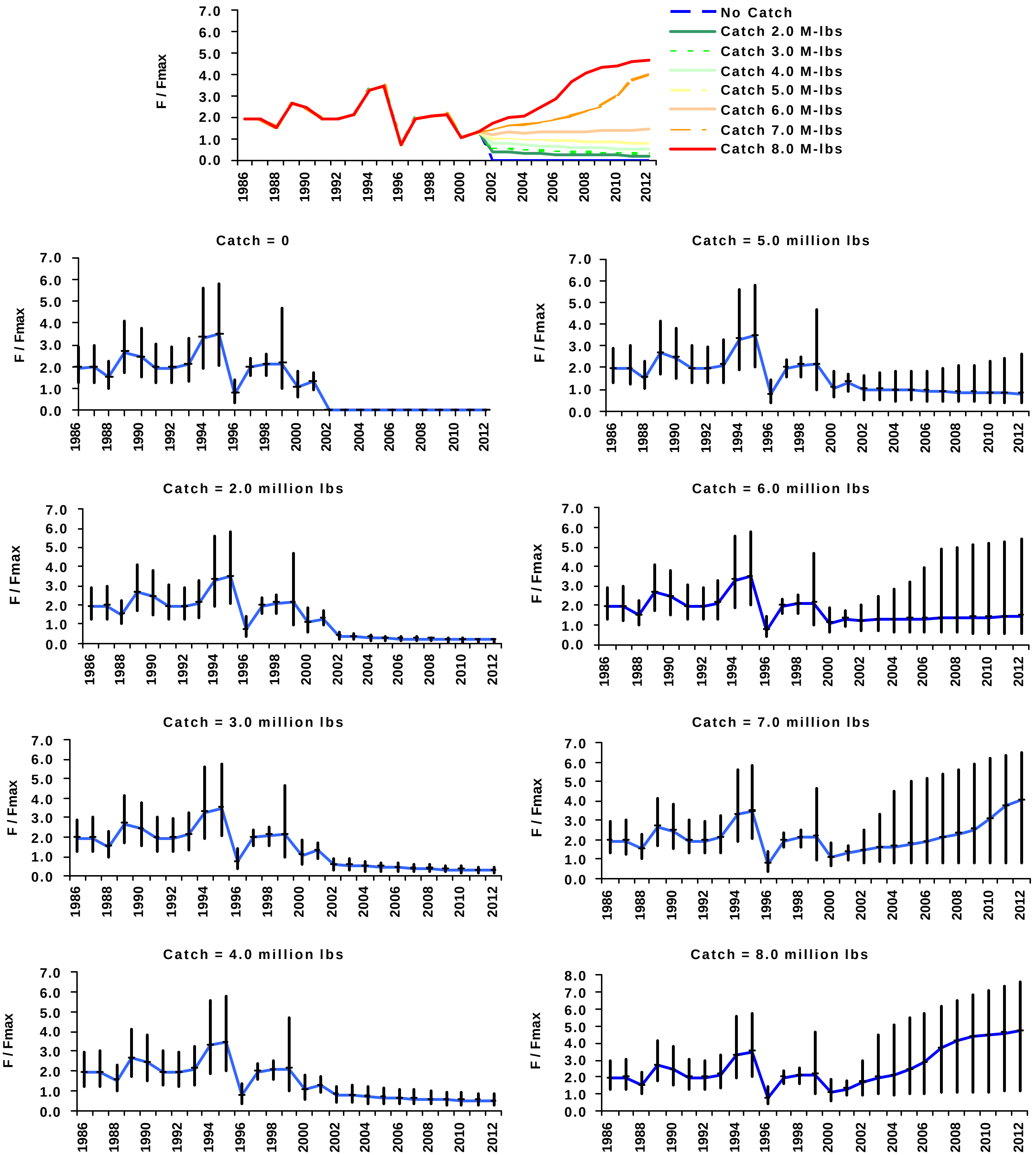



Figure 112. Historical and projected fishing mortality rate (F) relative to $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

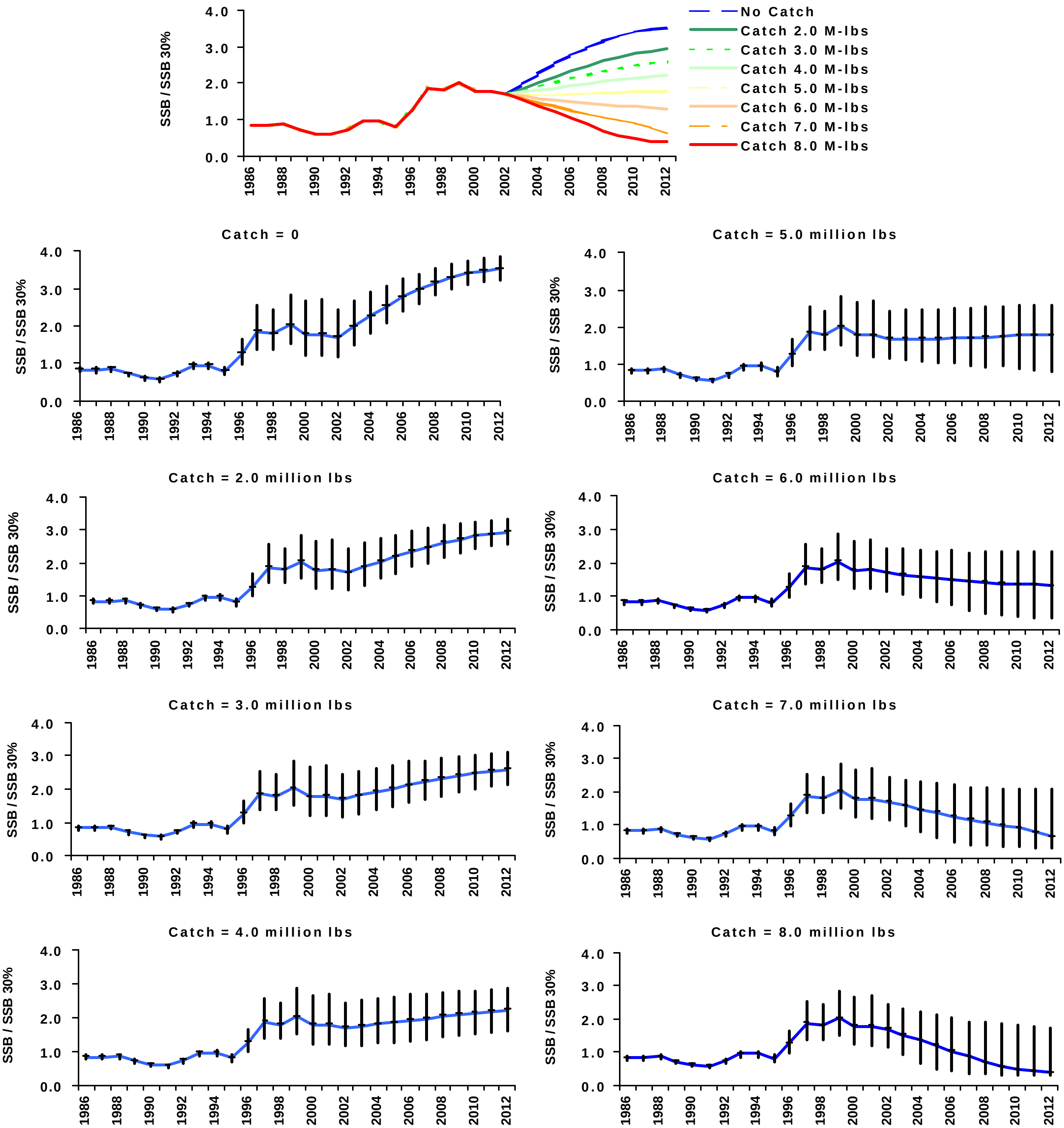



Figure 113. Historical and projected spawning stock biomass (SSB) relative to $SSB_{30\%}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

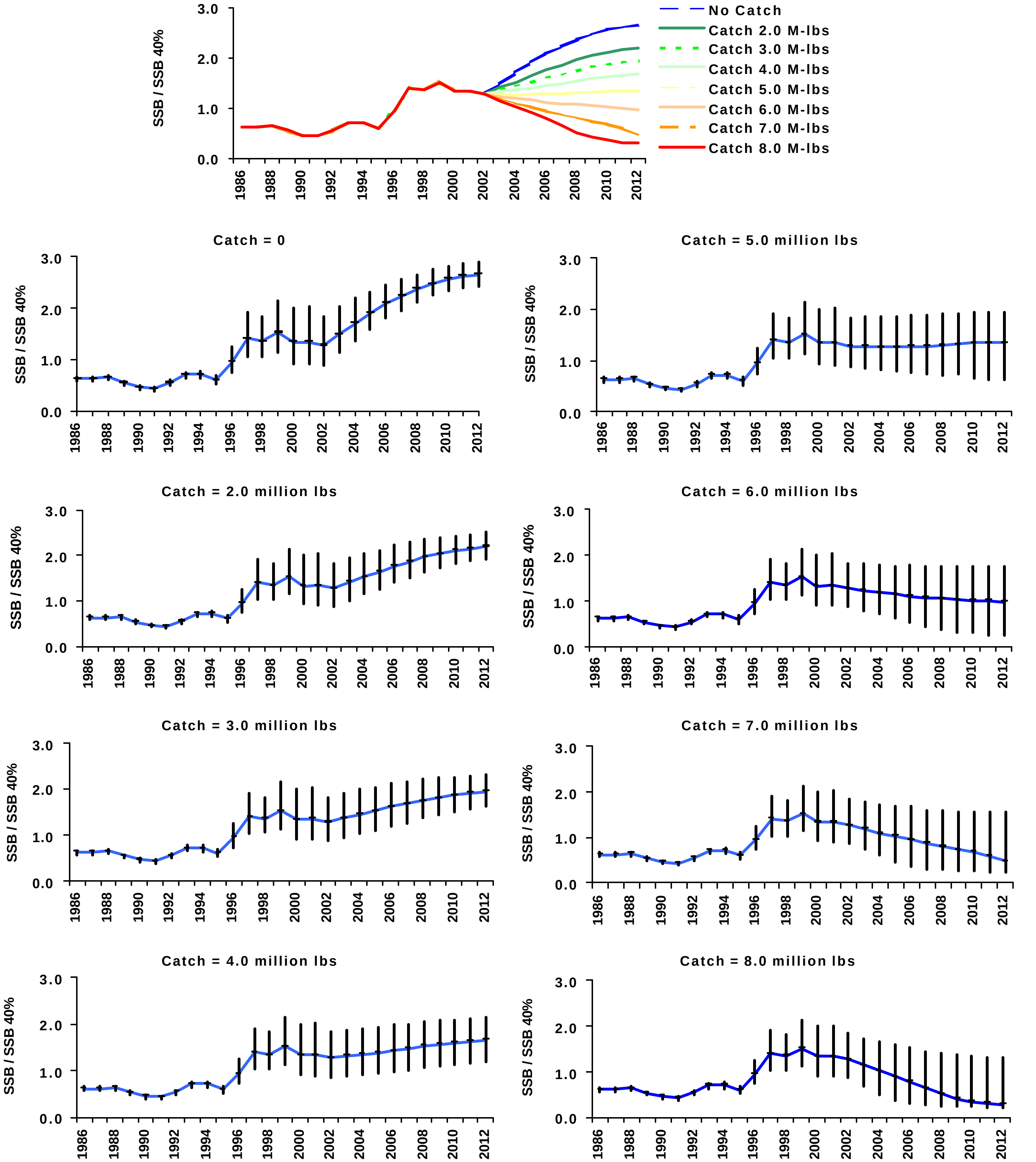



Figure 114. Historical and projected spawning stock biomass (SSB) relative to $SSB_{40\%}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012

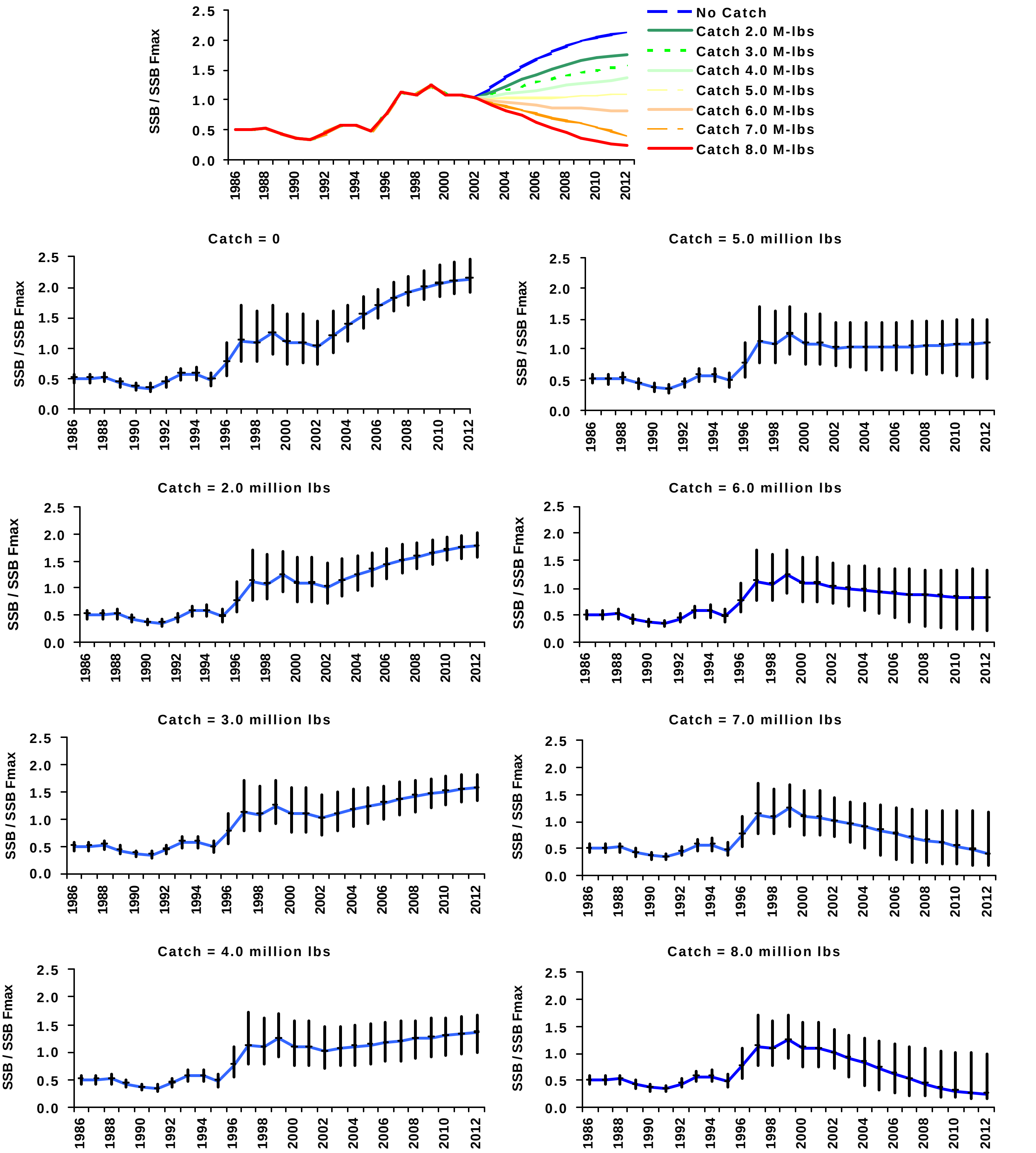



Figure 115. Historical and projected spawning stock biomass (SSB) relative to SSB at $F_{max}$ (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012.

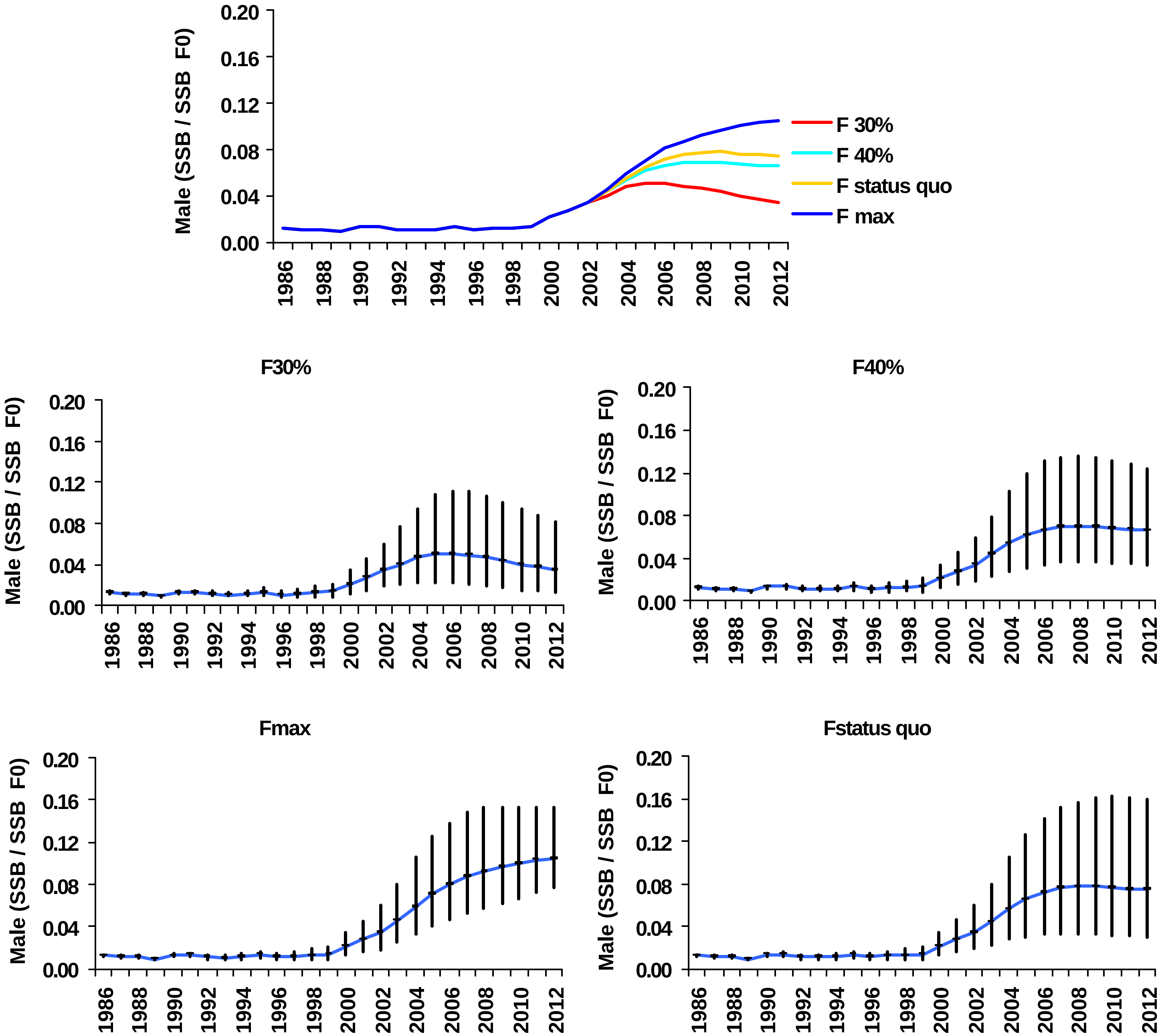



Figure 116. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume fishing in 2002-2012 at $F_{30\%}$, $F_{40\%}$, $F_{max}$, and $F_{statuis\ quo}$.

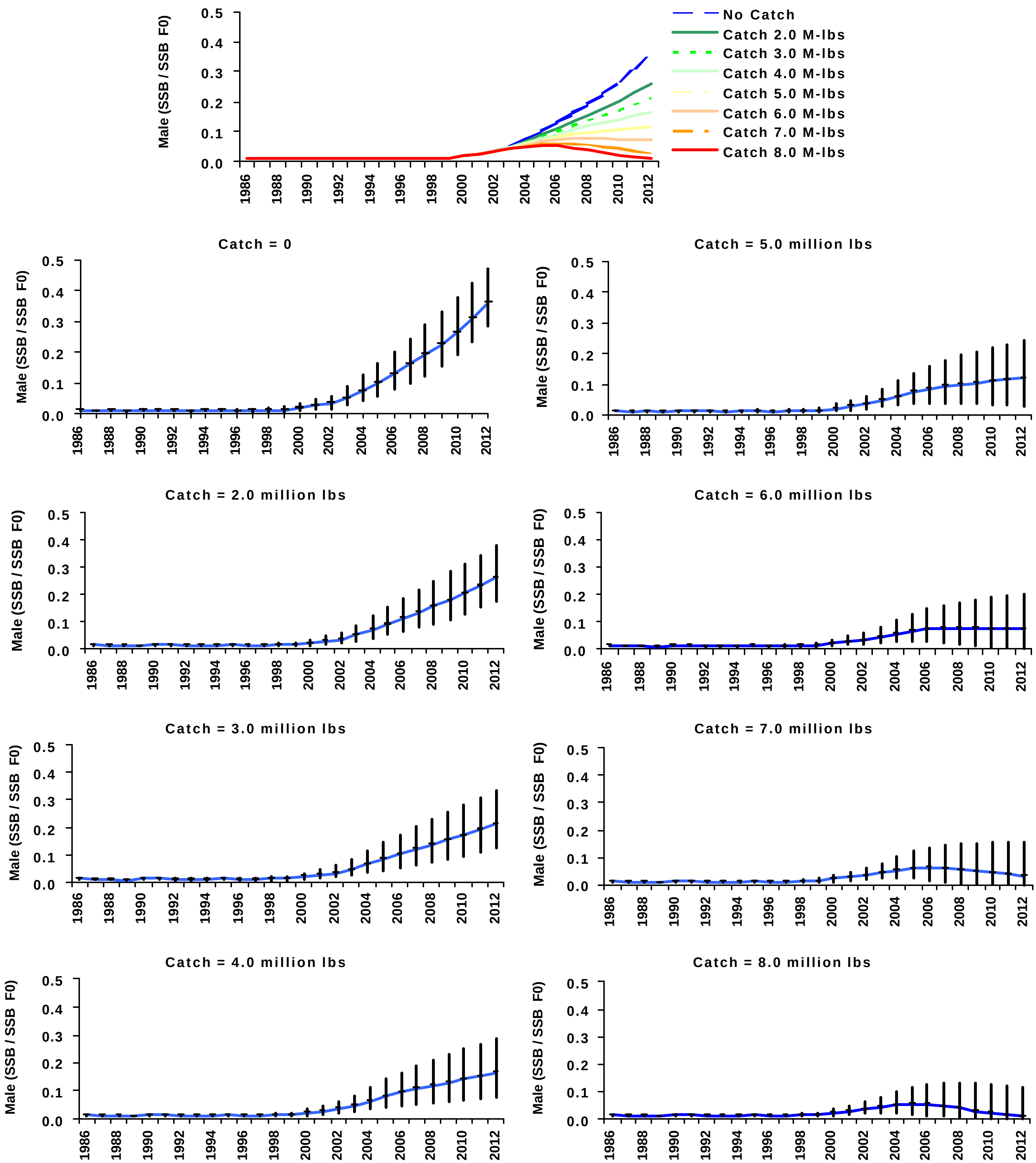



Figure 117. Historical and projected male spawning stock biomass (SSB) relative to male SSB in the unfished condition (median and the empirical 80% confidence interval) from bootstrapped sensitivity VPA using the ALK+ catch-at-age with year-constant index selectivity and average recruitment above the minimum 1986-1999 spawning stock size. Projections assume no catch or landings of 2 to 8 million pounds per year in 2002-2012

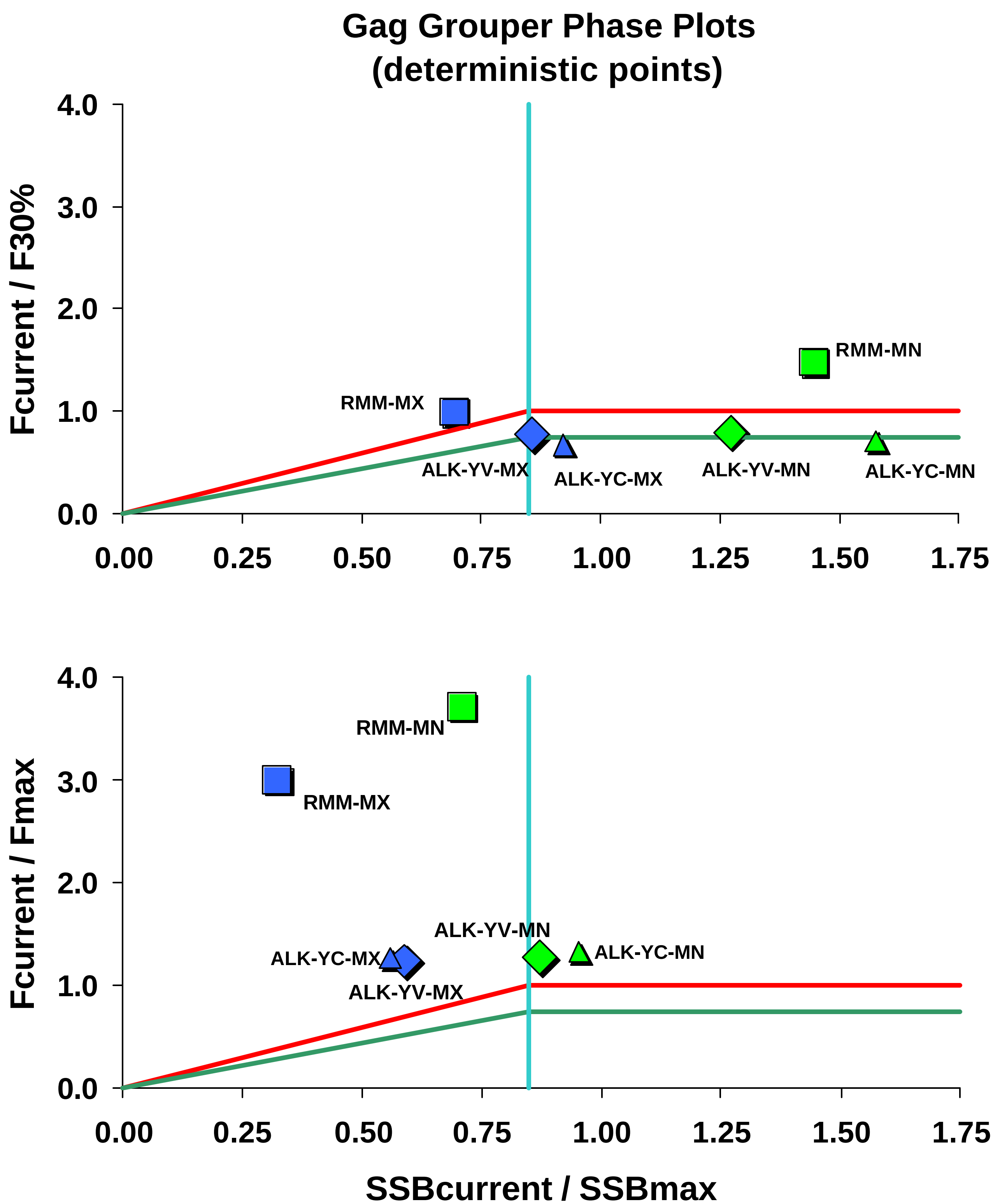



Figure 118. Deterministic estimates (not bias corrected) of current stock size and fishing mortality rate relative to reference statistics.

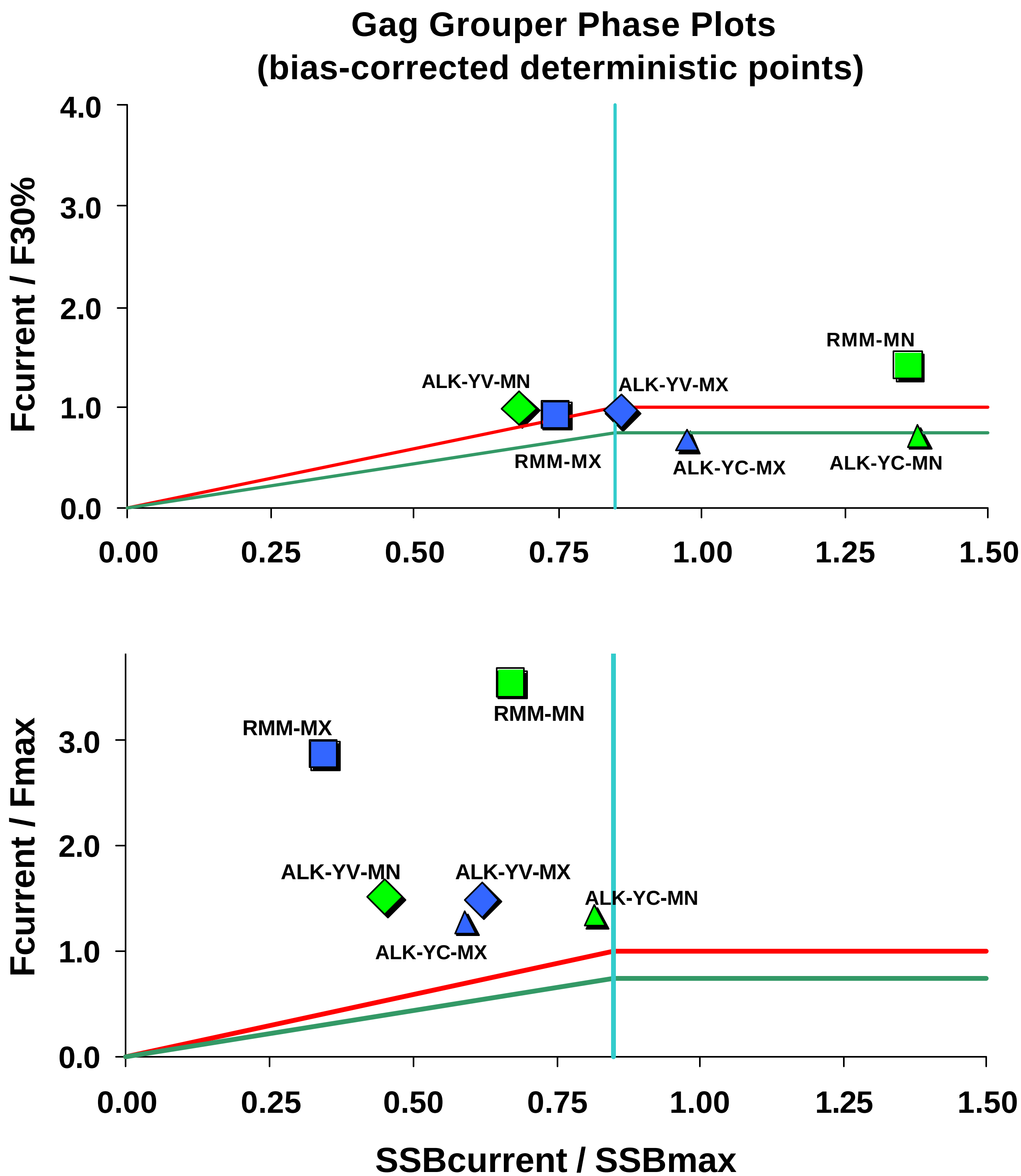



Figure 119. Bias corrected deterministic estimates of current stock size and fishing mortality rate relative to reference statistics.