Virtual population analysis of Gulf of Mexico king mackerel

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SEDAR38-RW-04

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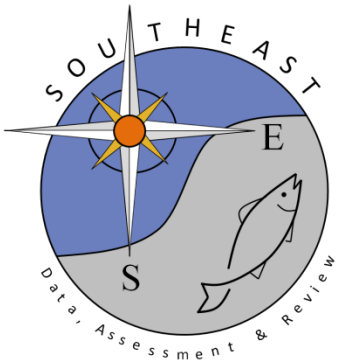

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Virtual Population Analyses of Gulf of Mexico King Mackerel

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SEDAR 38-RW-04

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Executive Summary

The methods and results of the continuity and updated virtual population analyses (VPA) conducted for SEDAR 38 stock assessment of Gulf of Mexico King Mackerel are summarized here and presented in detail in the attached report. The continuity VPA updated the previous assessment, SEDAR 16, with revised landings, discards, length composition, age samples, and indices without changing any assumptions about stock structure, catch composition, or model parameterization. Several key revisions were then made from the continuity to a SEDAR 38 base VPA, which included:

- Revision of stock structure and mixing assumptions, and associated reallocation of landings, discards, length samples, age samples, and indices.
- Truncation of the early time period 1981 to 1985, where no age information was available to estimate catch-at-age or fleet partial catch-at-age.
- Revision to the indices of abundance to exclude the MRFSS recreational private and charter index.
- Revision of life history information, including natural mortality, fecundity, maturity, growth, and length-weight relationships.
- Revised age composition of commercial and recreational discard mortalities to be comprised of age-0 individuals.
- Revised indices weighting by index coefficient of variation.

The main findings of the assessment included:

- Changes in stock structure and discard assumptions resulted in changes to fleet partial catch-at-ages, total catch-at-age estimates, and indices used in the VPA.
- Comparison of SSB and recruitment estimates between the continuity and base VPAs showed a similar long-term increasing stock trend, but diverged in the recent time period.
- The average spawning stock biomass from 2008 to 2012 was estimated to be 2,463 mt; estimates ranged 2,358 to 2,551 mt for that period.
- The average recruitment from 2008 to 2012 was estimated to be 3.26 million fish; estimates ranged 2.22 to 4.35 million fish for those years.
- The average apical fishing mortality from 2008 to 2012 was estimated to be 0.38; estimates ranged 0.28 to 0.46 for those years.
- Stock-recruitment estimates showed scattered pattern with no clear functional form or contrast in the range of recruitment across the range of SSB.
- Relatively strong recruitments were observed in 1989, 1990, 1993 to 1995, 2004, and 2007; and low recruitment years included 1986, 1987, 1996, 1997, 2008, and 2011.
- The Stock Synthesis model was selected as the preferred model over the VPA for estimation of benchmarks, stock projections, and management recommendations, and those determinations are presented in the SEDAR 38 Assessment Workshop Report.

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1. Introduction

SEDAR 38 was a benchmark assessment for Gulf of Mexico King Mackerel, which provided the opportunity to update the state of knowledge of the species and revise stock assessment modeling approaches accordingly. After extensive review of available information, several key assumptions were revised during the data workshop. One of the major conclusions of the life-history workgroup was a proposed revision to the definition of stock structure and winter mixing overlap with Atlantic King Mackerel. The result of this change in stock structure was reallocation of landings, discards, indices of abundance, age and length samples assigned to each stock, and corresponding changes in estimates of fleet partial catch-at-ages, and total catch-at-age -(principle inputs to the virtual population analysis (VPA). The base VPA in the previous assessment (SEDAR 16) used VPA-2BOX version 3.01, and an updated version of the software was used in this assessment, version 3.05.

A primary objective of the Assessment Workshop was to construct a continuity model that represented a strict update of the SEDAR 16 base VPA with landings, discards, indices of abundance, age and length samples updated to 2012; without changing any of the major assumptions of life history parameters, stock distribution model inputs or parameterization. The one primary change between SEDAR16 and the continuity run was a difference in the catch at age construction. Data and indices provided at the data workshop represented the continuity model inputs as these were constructed under the similar assumptions as the previous assessment. Section 2 of this report documents the review of continuity life history assumptions and data, VPA continuity methods, results, and comparison of the continuity VPA with the SEDAR 16 base model. After this objective was accomplished, the VPA was restructured to incorporate the revisions proposed during the Data Workshop and recommendations from the Assessment Panel based on review of the continuity model.

Revisions to the life-history parameters, landings, discards, indices of abundance, age information, and length samples were incorporated based on changes in the definition of stock distribution and discussion of VPA assumptions. Section 3 of this report documents the revisions to the data and model parameterization, results of the base VPA, and comparison with the continuity model. Time series estimates of fishing mortality, spawning stock biomass, and recruitment from the VPA base model are presented and discussed.

After the VPA base model was reviewed and evaluated, the Assessment Panel compared modeling approaches with the alternative base model, constructed in Stock Synthesis. The Stock Synthesis model was determined to be the preferred modeling platform, owing to the ability to more accurately model King Mackerel life-history, primarily sexually dimorphic growth and size structure, as well as more appropriately incorporate the various sources of data, specifically fleet associated length and age samples. In using Stock Synthesis, the assumptions of the age composition of the catch being known without error were loosened. Therefore, estimates of benchmarks, stock status, and projections were considered unnecessary for the VPA.

2. Continuity VPA

2.1 Continuity VPA Model Inputs

The continuity VPA was a combined sex, single stock model. Twelve age classes were defined as ages 0 to 10 and a plus group of fish age 11 and older. The modeled period was 1981 to 2012, with the annual time-step defined by fishing year, July 1 to June 31 of the following calendar year. All data were summarized by fishing year. A complete documentation of VPA assumptions and parameterization can be found in the SEDAR 16 Complete Assessment Report, available here: http://www.sefsc.noaa.gov/sedar/Sedar_Workshops.jsp?WorkshopNum=16. For comparative purposes and brevity of data summaries, all figures summarizing the continuity model results are presented with the revised base VPA results.

2.1.1 Life History Assumptions

The stock distribution was assumed to be Texas to the west coast of Florida at the Collier-Monroe county line during April 1 to October 31, with a winter mixing zone defined along Florida from the Collier-Monroe to the Flagler-Volusia counties lines during November 1 to March 31 (**Figure 1**). The stock mixing assumption was 50% Atlantic and 50% Gulf of Mexico stock composition within the mixing zone during the defined winter mixing season. Natural mortality (M) was assumed to follow a scaled Lorenzen curve, using a base M of 0.16. Maturity remained unchanged from the SEDAR 5 and SEDAR 16 base models. The assumed spawn date was July 1. Fecundity remained unchanged from SEDAR 16 base. The input values are listed in Table 1. The length-weight relationship was a power equation with parameters a=7.07e-6, b=3.0195.

2.1.2 Landings

Four fishing fleets were defined by sector and mode that included commercial handline, commercial non-handline, recreational headboat, recreational charter, and recreational private/shore. Tournament landings were assumed a negligible proportion of the recreational landings. Methods for landings estimation are described in the SEDAR 38 Data Workshop Report. Catch unit was number of fish. For the commercial fleets, this required a conversion from landings measured in whole pounds. This conversion was the annual fleet yield in pounds whole weight divided by the average weight of an individual calculated as the mean size of measured fish captured by the fleet and converted to weight using the length-weight conversion equation: $Weight = a \cdot Length^b$, where a and b values are listed in the above section. All landings within the mixing zone were assumed to be comprised of 50% Atlantic stock and 50% Gulf of Mexico stock. The landings data are summarized in **Figure 2**.

2.1.3 Discards

Commercial discards were assumed to be negligible and were not modeled, consistent with SEDAR 16 base. Estimates of total recreational discards were provided at the Data Workshop, and remained unchanged as input to the continuity model. The length composition of recreational headboat discards was assumed to be fish under the legal size limit, and the length

composition of recreational charter/private/shore discards was assumed equal to the length composition of the retained catch. Discard mortality was assumed to be 33% of live discards on recreational headboats and 20% of live discards on private boats, charter boats, and shore fishing.

2.1.4 Shrimp Bycatch

Estimates of shrimp bycatch of age-0 King Mackerel were based on catch rates of King Mackerel estimated from both observer data and SEAMAP survey data multiplied by shrimp fishing effort in the Gulf of Mexico (see SEDAR 16-DW-05 and addendum for methods). All shrimp bycatch removals were assumed to be age-0 fish. Estimates of shrimp bycatch are shown in **Figure 3**.

2.1.5 Indices of Abundance

Three fishery dependent indices, and two fishery independent surveys were included in the continuity VPA. The fishery dependent indices were the commercial logbook index of the commercial handline fleet, the Recreational Headboat Survey of the recreational headboat fleet, and the Marine Recreational Fisheries Statistics Survey (MRFSS) for the recreational private/charter/shore fleet. The fishery independent indices were the SEAMAP Gulf of Mexico Trawl Survey and the SEAMAP Larval Survey. The indices for the continuity model are listed in **Table 2** and **Figure 4**.

2.1.6 Length Composition Data

Length composition data were provided during the Assessment Workshop and are described and summarized in SEDAR 38-AW06. Note that the tournament length composition data were excluded from the estimation of size composition, age composition, and partial catch-at-age in the continuity model. A principal assumption of the VPA was that the length composition data accurately described the length composition of removals by fleet.

2.1.7 Partial Catch-at-age and Total Catch-at-age

Age-length keys and annual age-frequency distributions by fleet were provided at the Assessment Workshop. Methods of estimation are described in SEDAR 38-AW05. Key changes to the methods of age structure estimation were noted. Specifically, SEDAR 16 used a stochastic aging approach based on the von Bertalanffy growth model and length frequency distributions to fill fleet catch age-composition in years when little or no data were available. This assessment used a combined age-length key for the fleet, aggregated across years to fill missing years. This was agreed upon by the Assessment Panel to be an improvement in aging method and is a key difference between the continuity run and SEDAR 16. The annual age frequency distributions are compared across stock zones for each fleet in **Figures 5 to 10**. Fleet partial-catch-at-age (PCAA) was estimated as the annual fleet landings in number of fish times the annual fleet age-frequency distributions plus discard mortalities. Estimated fleet PCAA are presented in **Tables 3 to 5** and **Figures 11 to 14**. Note that the PCAA listed in **Tables 3 to 5** do not include discard mortalities since the standardized indices of abundance were based on

retained fish only; however, the PCAA shown in **Figure 11 to 14** include the discard mortalities to show the total estimated fleet removals. The total catch-at-age (CAA) was estimated as the sum of the individual fleet PCAA (including discard mortalities), plus 50% of fleet mixing zone PCAA, plus estimated shrimp bycatch (age-0 discard mortalities). The estimated CAA is shown in **Table 6** and **Figure 15**. Shrimp bycatch are not shown in the figures to better compare the age structure of ages 1 and older, which are relatively less compared to age-0 removals from shrimp bycatch. A comparison of the annual catch-at-age estimates between SEDAR 16 base and SEDAR 38 continuity VPA is presented in **Figure 16**, excluding shrimp bycatch.

2.2 Continuity VPA Parameterization

2.2.1 Terminal Year Fishing Mortality

Terminal year fishing mortality was estimated using the frequentist method (i.e., as free parameters with no prior distribution); starting values were set at 0.15, with a lower limit 0.001, and an upper limit of 3.0.

2.2.2 Plus Group Fishing Mortality Ratios

The plus group (ages 11 and older) fishing mortality was assumed equal to the estimated fishing mortality for age 10 fish; the fishing mortality ratio parameter was fixed at one for all years.

2.2.3 Stock-recruitment Parameters

No stock-recruitment relationship was assumed, that is, zero constraints were put on recruitment deviations related to spawning stock biomass. Stock-recruitment parameters were not directly estimated.

2.2.4 Stock Mixing Parameters

A single stock was assumed and stock mixing was not modeled. Landings from the winter mixing zone were assumed to be 50% Gulf of Mexico stock composition.

2.2.5 Tagging Data Assumptions

Tagging information was not included in the model.

2.2.6 Index Weighting

Indices were scaled to their respective means. Indices were weighted according to SEDAR 16 specifications to give all series equal weight overall but to still retain information on year-to-year precision. This was done by initially estimating the additive variance that would then scale each index variance to equal a common mean variance and then fixing this additional variance for successive model runs. (SEDAR 16-AW-09). Additive variance scalars were as follows: 0.441, MRFSS scalar = 0.518, SEAMAP Trawl scalar = 0, and SEAMAP Larval

scalar = 0.465.

2.2.7 Index selectivities

The selectivity of the SEAMAP Gulf of Mexico Trawl Index was assumed to be fully selective of age-0 individuals and zero selective of ages 1 and older. The SEAMAP Larval Survey was assumed to represent the relative abundance of the spawning stock, therefore the selectivity was fixed equal to the fecundity schedule. All fishery dependent index selectivities were directly estimated.

2.2.8 Parameter Estimation Options

The terminal year fishing mortality rates were constrained by penalizing annual deviations in the relative vulnerability (fishing mortality at age divided by the maximum fishing mortality rate at age) for ages 3 to 9 over the last three years with a standard deviation of 0.4. Catchability was estimated by the concentrated maximum likelihood routine assuming a lognormal distribution.

2.2.9 Model Diagnostics

Diagnostic criteria used to assess model convergence included goodness-of-fit criteria (likelihood and posterior density values for data components) and model fits to indices of abundance.

2.2.10 Uncertainty and Sensitivity Analyses

The objective of the continuity model was to compare the stock and fishery trends estimated for SEDAR 16, by updating the VPA with current data but strict adherence to the same assumptions and parameterizations. Therefore, bootstraps and sensitivity analyses were not run for the continuity VPA.

2.3 Continuity VPA Results

2.3.1 Fishing Mortality Estimates

Average estimated fishing mortality over the terminal five years (2008 to 2012) ranged 0.016 to 0.236 for age-0 and age-1 fish, 0.069 to 0.220 for fish ages 2 to 9, 0.234 for age-10, and was assumed equal to age 10 for the plus group (**Table 7**). Annual fishing mortality ranged less 0.006 to 0.634 for ages 0 and 1 across the time series, and ranged 0.03 to 1.06 for ages 2 and older for most years. Noticeable peaks in estimated fishing mortality were observed for age 0 and fish greater than age 4 for the period prior to 1996 (**Figure 17**). Estimates of fishing mortality in recent years were less than 0.4 for all ages.

2.3.2 Fleet Selectivity Estimates

Estimates of commercial handline, recreational headboat, and recreational charter/private/shore fisheries indicated an increasing selectivity pattern with age, with ages 8 to 10 being approximately fully selected (**Figure 18**).

2.3.3 Abundance-at-age Estimates

Abundance-at-age estimates showed a cyclical pattern corresponding to strong cohorts moving through the population (**Table 8, Figure 19**). The estimated decline in abundance of the older age classes during the early part of the time series is notable. A similar trend was estimated for SEDAR 16 base model, and no contradiction to previous model estimates was observed for the continuity model.

2.3.4 Spawning Stock Biomass Estimates

Estimates of spawning stock biomass showed a long-term steady increase from the lowest estimated biomass in 1985 to the highest estimated biomass in 2012 (**Table 9**). Modes corresponding to the periods of relatively strong cohorts were also apparent (**Figure 20**). In comparison to estimates from SEDAR 16 base, the continuity model demonstrated a shift in the magnitude of estimates to a lower biomass during the recent time period (**Figure 20**).

2.3.5 Recruitment Estimates

Recruitment estimates ranged between two million and ten million individuals (**Table 9**, **Figure 21**). Relatively high recruitment years included 1989, 1990, 1993, 1994, 1995, 2004 and 2007. Relatively low recruitment years included 1986, 1987, 1996, 1997, 2008, and 2011. Estimates of recruitment were consistent between the SEDAR 16 base and SEDAR 38 continuity VPAs for most the time series, but estimates from the continuity model diverged from the terminal three years of the SEDAR base VPA (**Figure 21**), although the terminal recruitment estimates are generally poorly estimated and usually the last three years are removed for projections and estimating the stock recruitment relationship.

2.3.6 Spawner-Recruit Relationship

Estimates of spawning stock biomass and recruitment demonstrated a scattered pattern with no clear functional form (**Figure 22**). A similar pattern was observed in estimates from the previous assessment.

2.3.7 Model Diagnostics

Model convergence statistics indicated a stable solution was reached with relatively few iterations. The model fits to the indices demonstrated a relatively good fit to commercial logbook index, but considerable divergence to the other indices, in comparison, particularly the recreational indices (**Figure 23**). The model predicted similar changes in magnitude in recruitment as the SEAMAP age-0 index; however, the model fit was not consistent across years.

Overall, the model performance was similar to the previous assessment, specifically the fits to the four indices of abundance.

2.4 Discussion

The continuity VPA demonstrated similar long-term trends in spawning stock biomass and recruitment as the SEDAR 16 base, although a distinct shift in the magnitude of spawning stock biomass was apparent for the terminal period. Recruitment estimates were similar in magnitude as the previous assessment. Since the VPA parameterizations were nearly identical between the models, the change in magnitude was expected to be a result of changes in the data. Two specific changes to data inputs were likely to cause the observed shift, as the majority of data methods remained unchanged from the previous assessment. The first change was revision to the estimated landings which incorporated improved methods, documented in the Data Workshop Report. The second was the change in age composition estimation methods for fleets and years lacking adequate age samples from a stochastic aging based on the growth model to a combined age-length key for the fleet across years. At the Assessment Workshop, a continuity sensitivity was presented that demonstrated that the change in biomass estimates was a direct result of the change in aging method which generally estimated a higher proportion of younger fish ages 1 to 3 and lower proportion of ages 4 and older fish in the catch. Substitution of the SEDAR 16 base model age-frequency scaled to the updated landings in the continuity model demonstrated that changes in the age structure density resulted in the observed shift in spawning stock biomass. Substitution of the SEDAR 16 base landings had little effect, in comparison. Therefore, it was concluded that the methods of estimation of the age structure resulted in the change in magnitude of spawning stock biomass, and that the revised methods represented an improvement in modeling approach. The recommendation was to use the revised aging method and associated age-frequency distributions for the data inputs to the base VPA.

3. Base VPA

3.1 VPA Model Inputs

Similar to the continuity model, the base VPA was a combined sex, single stock model. Twelve age classes were defined as ages 0 to 10 and a plus group of fish age 11 and older. The modeled period was 1986 to 2012, with the annual time-step defined by fishing year, July 1 to June 31 of the following calendar year. All data were summarized by fishing year. For comparative purposes and brevity of data summaries, all figures summarizing the continuity model results are presented with the revised base VPA results.

3.1.1 Life History Assumptions

The stock distribution was assumed to be Texas to Monroe County, Florida, including Monroe County north of U.S. highway, with a winter mixing zone defined to be Monroe County, Florida, south of U.S. highway 1, during November 1 to March 31 (**Figure 1**). Note that Monroe County, south of U.S. highway 1 was assumed to be Atlantic stock. This represented a significant change in stock distribution assumptions from the continuity model. The stock mixing assumption was 50% Gulf of Mexico and 50% Atlantic stock composition within the

mixing zone during the defined winter mixing season. Natural mortality (M), maturity, and fecundity estimates were reviewed and updated during the Assessment Workshop based on all available and current information. A detailed description of methods and assumptions applied to the revised life-history schedules can be found in the SEDAR 38 Assessment Workshop Report, Section 2.1. The assumed spawn date was July 1. The revised life-history input values are listed in **Table 10**. The length-weight relationship was updated with all available information, and was assumed to be a power equation with estimated parameters a=7.31e-6, b=3.0009.

3.1.2 Landings

Four fishing fleets were defined by sector and mode that included commercial handline, commercial non-handline, recreational headboat, and recreational charter/private/shore. Tournament landings were assumed to be negligible and were not modeled. Updated landing estimates were provided after the Data Workshop based on the revised stock structure assumptions, and were presented and reviewed during the pre-assessment webinar. Methods for landings estimation were consistent with continuity landings, but were estimated using the revised stock structure assumptions. The procedures of landings estimation are described in the SEDAR 38 Data Workshop Report. Catch unit was number of fish. For the commercial fleets, this required a conversion from landings measured in whole pounds. This conversion was the annual fleet yield in pounds whole weight divided by a weight frequency distribution calculated as the size frequency distribution converted to weight using the length-weight conversion equation: $Weight = a \cdot Length^b$, where a and b values are listed in the above section. This represented a change in methods from the continuity model, where commercial landings in numbers were calculated from the mean weight rather than the weight frequency. A comparison of the proportions of landings assigned to the Gulf of Mexico, Atlantic, and winter mixing zones between the continuity and revised stock structures is shown in **Figure 24**. All landings within the mixing zone were assumed to be comprised of 50% Atlantic stock and 50% Gulf of Mexico stock. The landings data are summarized in **Figure 2**.

3.1.3 Discards

Commercial discards were included in the model, which represented a change in methods from the continuity which excluded commercial discards. Estimates of total recreational discards were revised based on the updated stock distributions. The length composition of recreational discards was evaluated during the Assessment Workshop based on observer data provided by the Florida Fish and Wildlife Conservation Commission (unpublished data). Based on this evaluation, the discard size assumptions of recreational fleets was changed to be comprised of fish less than 50cm, and all age-0 (**Figure 25**). This represented a change in the continuity methods in which the length composition of recreational charter/private/shore discards was assumed equal to the length composition of the retained catch. Discard mortality was assumed to be 22% of live discards on recreational headboats and 20% of live discards on private boats, charter boats, and shore fishing. The discard mortality rate assumption of headboats was changed from the continuity model which assumed 33% mortality.

3.1.4 Shrimp Bycatch

The methods for estimation of shrimp bycatch of age-0 King Mackerel were similar to those used in SEDAR 16 where a combined GLM model using both observer, SEAMAP survey and other survey data was used to estimate by catch rates and the effects of bycatch reduction devices. A complete description of the methods and estimates can be found in SEDAR 38-RW-03. Similar to the continuity model, all shrimp bycatch removals were assumed to be age-0 fish. Estimates of shrimp bycatch are shown in **Figure 3**.

3.1.5 Indices of Abundance

Two fishery dependent CPUE indices and two fishery independent surveys were included in the base VPA. The fishery dependent indices were the commercial logbook index of the handline fleet and the Recreational Headboat Survey of the recreational headboat fleet. The fishery independent indices were the SEAMAP Gulf of Mexico Trawl Survey and the SEAMAP Larval Survey. Changes in indices from the continuity methods included: (1) exclusion of the Marine Recreational Fisheries Statistics Survey (MRFSS) survey for the recreational private/charter/shore fleet, and (2) revision to the spatial coverage of the recreational headboat index to exclude samples from Monroe County, Florida, year-round. All revised indices were provided after the Data Workshop and were presented and reviewed during the pre-assessment webinar. The indices for the base VPA are listed in **Table 11** and compared graphically in **Figure 4**.

3.1.6 Length Composition Data

Length composition data were provided during the Assessment Workshop and are described and summarized in SEDAR 38-AW06. Note that the tournament length composition data were not included in the estimation of size composition, age composition, and partial catch-at-age in the base model. A principal assumption of the VPA was that the length composition data accurately described the length composition of removals by fleet.

3.1.7 Partial Catch-at-age and total catch-at-age

Age-length keys and annual age-frequency distributions by fleet were revised based on the updated stock structure definitions and were provided at the Assessment Workshop. Methods of estimation are described in SEDAR 38-AW05. Key changes to the methods of age structure estimation from the previous assessment, documented above in Section 2.1.7, were consistent for the continuity and base models. The annual age frequency distributions are presented for each fleet in **Figures 26 to 31**. Fleet partial-catch-at-age (PCAA) was estimated as the annual fleet landings in number of fish times the annual fleet age-frequency distributions plus fleet discard mortalities. Note that discards for all fleets were assumed to be age-0 fish. Estimated fleet PCAA are presented in **Tables 12** and **13** for the commercial handline and recreational headboat indices respectively, and **Figures 11 to 14** for all recreational fleets. Note that the PCAA listed in **Tables 12** and **13** do not include discard mortalities since the standardized indices of abundance were based on retained fish only; however, the PCAA shown in **Figure 11 to 14** include the discard mortalities to show the total estimated fleet removals in

comparison to the continuity PCAAs. The total catch-at-age (CAA) was estimated as the sum of the individual fleet PCAA including discard mortalities, plus 50% of fleet mixing zone PCAA, plus estimated shrimp bycatch (age-0 discard mortalities). The estimated total CAA is shown in **Table 14** and **Figure 15**.

3.2 Base VPA Parameterization

3.2.1 Terminal Year Fishing Mortality

Terminal year fishing mortality was estimated using the frequentist method (i.e., as free parameters with no prior distribution); starting values were set at 0.4, with a lower limit 0.001, and an upper limit of 2.0.

3.2.2 Plus Group Fishing Mortality Ratios

No change was made from the continuity model parameters. The plus group (ages 11 and older) fishing mortality was assumed equal to the estimated fishing mortality for age 10 fish; the fishing mortality ratio parameter was fixed at one for all years.

3.2.3 Stock-recruitment Parameters

No change was made from the continuity model parameters. No stock-recruitment relationship was assumed, that is, zero constraints were put on recruitment deviations related to spawning stock biomass. Stock-recruitment parameters were not directly estimated.

3.2.4 Stock Mixing Parameters

No change was made from the continuity model parameters. A single stock was assumed and stock mixing was not modeled. Landings from the winter mixing zone were assumed to be 50% Gulf of Mexico stock composition.

3.2.5 Tagging Data Assumptions

No change was made from the continuity model parameters. Tagging information was not included in the model.

3.2.6 Index Weighting

Indices were scaled by their respective means. Indices were weighted by the estimated coefficients of variation, representing a change from continuity methods which used equal weighting and additive variance scalars.

3.2.7 Index selectivities

No change was made from the continuity model parameters. The selectivity of the SEAMAP Gulf of Mexico Trawl Index was assumed to be fully selective of age-0 individuals

and zero selective of ages 1 and older. The selectivity of the SEAMAP Larval Survey was assumed equal to the fecundity schedule. Vulnerability estimates of ages 3 to 9 were constrained for the terminal three years to a standard deviation equal to 0.4 from the previous year.

3.2.8 Parameter Estimation Options

No change was made from the continuity model parameters. The terminal year fishing mortality rates were constrained by penalizing annual deviations in the relative vulnerability (fishing mortality at age divided by the maximum fishing mortality rate at age) for ages 3 to 9 over the last three years with a standard deviation of 0.4. Catchability was estimated by the concentrated maximum likelihood routine assuming a lognormal distribution.

3.2.9 Model Diagnostics

Diagnostic criteria used to assess model convergence included goodness-of-fit criteria (likelihood and posterior density values for data components), limitation on the number of iterations to convergence, and model fits to indices of abundance.

3.2.10 Uncertainty and Sensitivity Analyses

Uncertainty in estimates of fishing mortality and spawning stock biomass was assessed by parametric bootstrapping, and sensitivity analyses were conducted by changing key model assumptions and comparing the results with the base run. Sensitivities presented in this report include an indices jackknife analysis in which each index of abundance was iteratively removed to evaluate the influence on model results, and a retrospective analysis in which the terminal 5 years of data were sequentially removed to evaluate the influence of individual terminal year data on the results.

3.3 Base VPA Results

3.3.1 Fishing Mortality Estimates

Average estimated fishing mortality over the terminal five years (2008 to 2012) was 0.316 for age 0, ranged 0.02 to 0.10 for age-1 to age-4 fish, 0.16 to 0.31 for fish ages 5 to 9, 0.32 for age-10, and was assumed equal to age 10 for the plus group (**Table 15**). Annual fishing mortality ranged 0.21 to 0.74 for age-0 individuals, 0.01 to 0.32 for ages 1 to 4, 0.03 to 0.66 for ages 5 to 9, and 0.10 to 0.63 for age 10 and the plus group across the time series. Relatively high fishing mortality was estimated prior to 1996 for age-0 and ages 4 to 9, fishing mortality of ages 1 and 2 were relatively lower in comparison. In the recent period since the last assessment, 2007 to present, fishing mortality was estimated to be less than 0.42 for all ages, and generally increased across ages (**Figure 17**).

3.3.2 Fleet Selectivity Estimates

The selectivity of the commercial handline and recreational headboat fleets was estimated to be approximately asymptotic, with fish age 8 and older estimated to be fully selected to the

handline fishery, and fish age 9 and older fully selected to the recreational headboat fishery (**Figure 18**). Estimated selectivity patterns from the base VPA were similar to the estimates from the continuity model.

3.3.3 Abundance-at-age Estimates

Abundance-at-age estimates showed a cyclical pattern corresponding to strong cohorts moving through the population (**Table 16, Figure 19**). In general, the estimated abundance of older age classes declined during the early part of the time series. This pattern was consistent with estimates from the continuity model. The primary difference between the models was the estimates of age 0 fish, resulting from changes to estimates of shrimp bycatch.

3.3.4 Spawning Stock Biomass Estimates

Estimates of SSB showed an increasing trend across the time series from a low spawning stock biomass in 1986 to a peak in 2008 (**Table 17, Figure 20**). Modes corresponding to the periods of relatively strong cohorts were consistent with those observed for the continuity model (**Figure 20**). Similar to the estimates of abundance, the overall stock trend was in agreement with the continuity model estimates that demonstrated a long-term increase across the time series, with the exception of the most recent time period, 2006 to 2012, where estimates diverged from the continuity model from a continuing increasing trend to a relatively stable SSB.

3.3.5 Recruitment Estimates

Recruitment estimates ranged between two million and ten million individuals (**Table 17**, **Figure 21**). Relatively high recruitment years included 1989, 1990, 1993, 1994, 1995, 2003, 2004, and 2007. Relatively low recruitment years included 1986, 1987, 1996, 1997, 2008 and the recent time period beginning in 2010. Recruitment trends were consistent with those observed for the continuity model (**Figure 21**).

3.3.6 Spawner-Recruit Relationship

Similar to the continuity VPA, estimates of spawning stock biomass and recruitment from the base VPA demonstrated a scattered pattern with no clear functional form (**Figure 22**). Comparison of spawner-recruitment patterns with the continuity model demonstrated similarity in the range of estimated recruitment, but a shift in the estimates of SSB was observed to a higher estimated biomass (**Figure 22**).

3.3.7 Model Diagnostics and Sensitivities

The base VPA demonstrated stable convergence with relatively few iterations, and across different starting values for terminal F and search parameters. Fits to the indices of abundance were generally similar to the observed fits of the continuity model (**Figure 23**). The model predictions demonstrated similar long-term trends to the observed values for the commercial logbook index and the SEAMAP trawl survey, but diverged from the other indices, in comparison. The magnitude of inter-annual change in indices was underestimated for the

headboat index and larval survey in particular. Bootstrap and sensitivity analyses indicated stability in estimates of fishing mortality, abundance and biomass for the majority of years. The overall long-term trends in fishing mortality-at-age and abundance-at-age did not vary greatly across bootstrap iterations (**Figures 32 and 33**). The indices jackknife sensitivity showed that estimates of recruitment and spawning stock biomass were not sensitive to individual indices (**Figure 34**). In fact, trends in recruitment estimates were well determined and stable across most model sensitivities (**Figures 33 to 36**). The retrospective analysis demonstrated no bias in model estimates of spawning stock biomass (**Figure 35**), as the removal of sequential years of data resulted in fairly consistent biomass estimates. The model produced relatively stable long-term trends for estimates of recruitment, fishing mortality-at-age, abundance-at-age, and spawning stock biomass.

3.4 Discussion

The base VPA of Gulf of Mexico King Mackerel indicated an increasing long-term trend in spawning stock biomass, with periods of relatively good recruitment resulting in pulses of increased abundance in following years and higher spawning stock biomass as the fish mature. It was clear from the observed age-frequency distributions that these cohorts supported the fisheries for multiple years. Periods of low recruitment were also apparent which resulted in higher fishing mortality on these relatively weak year classes. In general, estimates of fishing mortality and spawning stock biomass were not highly sensitive to model assumptions, and the long-term trends in recruitment were particularly robust. The causes of these cyclical patterns in recruitment remain unknown. Further work is recommended to determine the principle factors leading to strong versus weak recruitment in the Gulf of Mexico, which support multiple fisheries and result in changes in spawning stock abundance and biomass.

Estimates of spawning stock biomass appeared to be well determined, as demonstrated by the sensitivity analyses and lack of divergence in stock trends from the continuity VPA. Despite several revisions to the model, the long-term perception of the spawning stock trend did not change greatly, particularly for the early years despite the differences in start date between the BASE and the continuity model. Results from the sensitivity analyses were relatively robust, indicating model stability to alternative parameterization and indices. Stock benchmarks, and associated stock and fishery status were not estimated from the base VPA, as the Stock Synthesis base model was the preferred advice model by the Assessment Panel. The reasons for this decision were (1) the Stock Synthesis model estimated sex-specific growth within the model, (2) Stock Synthesis was thought to more appropriately model shrimp bycatch and some of the fleet specific age and length composition data, (3) Stock Synthesis could account for information gaps, such as missing age-frequency information for a given fleet or year.

4. Tables

Table 1. Life history assumptions in the continuity VPA of Gulf of Mexico King Mackerel.

Age	0	1	2	3	4	5	6	7	8	9	10	11+
M	0.76	0.27	0.24	0.22	0.21	0.20	0.19	0.18	0.18	0.17	0.17	0.16
Maturity	0.00	0.16	0.53	0.70	0.86	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Fecundity	0.00	0.15	0.27	0.40	0.53	0.67	0.80	0.93	1.04	1.15	1.24	1.52

Table 2. Indices of Abundance of Gulf of Mexico King Mackerel used in the Continuity VPA.

	Headboat		Logbook		MRFSS		SEAMAP_Plankton		SEAMAP_Trawl	
units	number		biomass		number		number		number	
GLM	delta-lognormal		delta-lognormal		delta-lognormal		delta-lognormal		delta-lognormal	
ages	1-6		1-11		1-8		1-11		0	
	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1972	-	-	-	-	-	-	-	-	3.5	0.37
1973	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	1.3	0.57
1975	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	0.07	1.1
1977	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	0.86	0.67
1979	-	-	-	-	-	-	-	-	1.11	0.47
1980	-	-	-	-	-	-	-	-	0.06	1.1
1981	-	-	-	-	0.71	0.4	-	-	0.2	0.8
1982	-	-	-	-	0.45	0.38	-	-	0.09	1.1
1983	-	-	-	-	0.9	0.4	-	-	-	-
1984	-	-	-	-	0.49	0.36	-	-	0.82	0.58
1985	-	-	-	-	0.54	0.39	-	-	0.27	0.53
1986	0.71	0.17	-	-	0.46	0.31	0.11	0.53	0.51	0.8
1987	0.66	0.17	-	-	1.09	0.27	0.38	0.32	0.06	1.1
1988	0.79	0.19	-	-	0.72	0.29	0.59	0.43	0.63	0.37
1989	0.81	0.18	-	-	0.92	0.3	0.8	0.33	0.41	0.57
1990	0.55	0.16	-	-	1.27	0.29	0.66	0.33	1.45	0.26
1991	1.29	0.15	-	-	1.26	0.27	0.7	0.31	0.22	0.44
1992	1.2	0.15	-	-	1	0.26	0.63	0.23	0.3	0.47
1993	0.86	0.14	0.676	0.147	0.97	0.27	1.22	0.21	2.35	0.23
1994	1.16	0.13	0.735	0.121	1.2	0.26	1.01	0.22	0.87	0.35
1995	1.27	0.13	0.906	0.11	1.07	0.28	1.94	0.2	0.61	0.43
1996	1.39	0.13	0.867	0.095	1.28	0.27	0.74	0.26	0.6	0.37
1997	1.16	0.16	1.028	0.084	1.49	0.26	1.29	0.2	1.15	0.3
1998	1.04	0.14	1.198	0.078	1.08	0.26	-	-	1	0.29
1999	0.95	0.16	0.941	0.076	0.92	0.25	0.92	0.22	0.99	0.29
2000	0.88	0.14	1.044	0.072	1.23	0.25	0.91	0.27	0.51	0.41
2001	0.69	0.15	0.85	0.082	1.12	0.25	1.54	0.2	1.43	0.28
2002	0.73	0.14	0.945	0.074	1.25	0.25	1.42	0.21	1.24	0.31
2003	1	0.14	0.887	0.083	0.98	0.25	1.05	0.22	2.49	0.2
2004	0.67	0.15	0.867	0.085	1.01	0.25	1.45	0.21	2.18	0.22
2005	1.01	0.15	0.698	0.102	0.85	0.26	-	-	1.45	0.21
2006	1.28	0.14	0.913	0.088	1.56	0.25	1.15	0.25	1.59	0.26
2007	1.18	0.14	1.092	0.085	0.92	0.25	1.4	0.22	2.65	0.2
2008	1.07	0.16	0.949	0.083	0.84	0.26	-	-	0.23	0.57
2009	1.57	0.13	1.181	0.077	1.39	0.25	0.82	0.24	1.5	0.23
2010	0.95	0.16	1.431	0.104	1.01	0.26	1.13	0.25	1.15	0.28
2011	1.15	0.14	1.306	0.106	0.8	0.26	1.27	0.25	0.31	0.66
2012	0.97	0.13	1.404	0.101	1.21	0.25	0.86	0.26	0.85	0.44

Table 3. Commercial Handline Partial Catch-at-age Input to the Continuity VPA of Gulf of Mexico King Mackerel.

FishingYear	Fleet	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1981	HL	0	5	1,251	2,207	2,055	891	71	65	61	0	0	215
1982	HL	450	8,029	10,669	20,918	12,464	232	14,868	131	0	0	0	9,403
1983	HL	4	1,000	3,718	4,652	6,336	6,760	5,514	4,566	3,462	2,406	1,575	3,279
1984	HL	15	605	5,459	9,526	12,535	12,316	9,723	7,833	5,852	3,962	2,525	5,241
1985	HL	26	3,180	11,288	14,002	14,726	11,995	8,781	6,807	4,920	3,352	2,137	4,955
1986	HL	0	1,361	3,698	5,039	12,116	9,971	4,119	3,002	2,581	2,493	1,641	2,940
1987	HL	0	263	1,245	3,814	3,865	3,031	2,244	2,012	2,757	1,950	465	6,902
1988	HL	0	675	3,200	4,566	5,768	3,183	6,527	4,334	1,379	3,276	3,786	5,464
1989	HL	213	2,671	3,181	4,735	8,321	8,295	3,014	5,618	3,259	1,336	2,827	8,504
1990	HL	0	1,035	2,629	2,103	3,036	3,181	3,080	2,095	4,489	2,161	697	11,803
1991	HL	533	6,004	11,463	9,144	5,020	6,104	6,167	3,466	1,404	6,625	1,398	5,352
1992	HL	0	11,330	27,928	29,323	20,273	10,203	11,973	5,913	5,712	1,582	5,015	4,840
1993	HL	131	8,875	22,187	26,231	19,837	9,126	4,088	5,115	2,842	2,372	393	8,132
1994	HL	0	15,155	23,103	22,511	25,493	16,043	6,937	2,600	3,881	2,292	1,774	3,402
1995	HL	35	5,985	17,700	16,438	12,916	11,339	9,963	5,021	2,094	1,919	1,770	2,427
1996	HL	0	30,256	31,943	24,178	9,379	6,735	6,580	5,599	2,034	1,220	383	1,329
1997	HL	0	15,870	49,335	38,344	17,973	12,469	8,313	7,804	4,699	3,154	3,056	3,269
1998	HL	0	21,600	41,624	29,924	40,644	13,468	4,387	2,877	2,073	2,668	1,173	289
1999	HL	0	16,344	41,885	26,746	29,898	22,923	13,588	6,028	5,615	3,909	1,171	4,115
2000	HL	0	12,378	14,968	18,250	15,601	21,497	5,312	16,281	5,562	2,113	3,223	4,179
2001	HL	643	8,716	28,248	20,472	14,044	11,435	11,497	10,582	6,738	1,446	2,559	7,245
2002	HL	104	12,989	24,242	16,844	14,075	8,746	7,220	7,335	5,402	2,842	1,254	3,449
2003	HL	0	9,234	36,331	21,912	18,492	11,839	7,432	4,000	5,333	3,543	2,185	3,161
2004	HL	0	4,708	18,922	17,161	19,264	14,656	8,701	6,015	3,833	3,531	1,791	2,001
2005	HL	94	4,627	20,206	18,706	19,765	11,750	7,889	6,620	4,773	3,158	2,602	4,732
2006	HL	31	4,076	28,894	27,273	27,084	24,550	14,195	10,701	8,530	3,100	3,022	5,934
2007	HL	0	1,359	13,254	35,606	35,729	19,417	16,281	11,153	8,805	6,488	2,240	4,140
2008	HL	0	6185	10897	16834	29357	26836	16049	16407	7150	4105	1956	1998
2009	HL	150	4,191	46,191	24,167	28,132	33,187	23,716	11,275	7,836	3,213	1,936	3,946
2010	HL	0	1,252	10,992	36,065	23,965	14,043	18,085	11,865	4,798	4,407	1,695	3,221
2011	HL	0	1,516	6,261	11,450	33,395	17,802	14,757	18,678	11,685	4,326	4,980	5,855
2012	HL	0	1,443	7,431	7,093	8,604	30,017	14,253	9,878	14,997	8,931	3,225	6,889

Table 4. Recreational Headboat Partial Catch-at-age Input to the Continuity VPA of Gulf of Mexico King Mackerel.

FishingYear	Fleet	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1981	HB	16	887	3,095	3,402	2,879	1,913	1,245	826	596	445	286	674
1982	HB	12	660	2,303	2,530	2,142	1,423	926	615	443	331	212	501
1983	HB	15	775	2,703	2,970	2,514	1,671	1,088	722	521	390	250	587
1984	HB	11	591	2,060	2,264	1,916	1,273	829	550	397	297	191	447
1985	HB	2	391	2,265	3,470	4,192	3,880	2,929	2,274	1,642	1,067	659	1,367
1986	HB	0	260	1,068	1,060	2,232	1,554	529	326	323	315	214	257
1987	HB	0	340	1,158	2,093	1,576	1,039	590	527	438	458	65	746
1988	HB	0	515	1,454	1,849	1,501	817	1,196	624	235	400	482	367
1989	HB	26	202	1,063	1,974	2,505	1,868	800	1,012	552	250	307	775
1990	HB	0	472	2,398	1,817	1,816	971	772	216	604	221	14	405
1991	HB	58	1,162	5,246	3,911	1,584	1,465	858	530	220	636	117	280
1992	HB	0	681	4,589	5,125	2,887	1,306	1,388	728	679	185	530	567
1993	HB	61	649	3,378	5,250	3,907	1,703	820	954	513	383	63	1,396
1994	HB	0	2,851	4,323	3,569	3,833	2,373	1,022	389	550	327	212	392
1995	HB	27	1,534	4,648	4,602	3,372	2,573	1,828	870	342	317	265	329
1996	HB	0	2,112	5,284	5,317	2,423	1,803	1,843	1,620	606	390	128	517
1997	HB	0	1,031	3,865	3,693	2,031	1,734	1,475	1,435	1,114	1,011	1,152	1,254
1998	HB	0	517	1,531	2,097	4,468	2,204	1,009	847	653	871	415	431
1999	HB	0	1009	2874	3299	4127	2981	2174	717	1034	554	345	1318
2000	HB	0	1417	1792	2433	1982	2405	634	1660	561	106	370	394
2001	HB	49	697	2829	2384	1759	1483	1487	1352	941	173	329	959
2002	HB	13	1930	4910	4139	3528	2024	1616	1725	1059	526	243	574
2003	HB	0	405	2809	2681	2722	1728	1216	653	903	548	350	495
2004	HB	0	697	3328	3588	4322	3251	1867	1236	855	828	389	449
2005	HB	5	553	3953	4419	4962	3116	1929	1525	1116	702	539	827
2006	HB	0	421	3973	3829	4072	3568	2177	1460	1192	527	381	935
2007	HB	0	254	1552	4062	3991	1973	1596	1249	885	577	197	494
2008	HB	0	1757	2174	2069	2938	2687	1739	1722	876	597	379	612
2009	HB	11	462	4039	2080	2326	3125	2646	1290	1114	462	330	736
2010	HB	0	97	1243	4344	2950	1719	2030	1283	479	494	169	407
2011	HB	0	521	1340	1766	3967	2060	1530	2170	1245	490	585	705
2012	HB	0	232	1105	1038	1171	3541	1696	1194	1708	1071	380	846

Table 5. Recreational Charter, Private, and Shore Fleet Partial Catch-at-age Input to the Continuity VPA of Gulf of Mexico King Mackerel.

FishingYear	Fleet	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1981	CPS	160	24,532	31,113	18,146	13,715	9,207	5,785	4,190	3,463	2,479	2,728	19,679
1982	CPS	15,781	98,296	79,672	81,250	89,823	84,692	66,671	57,690	44,706	35,448	25,188	60,469
1983	CPS	67	9,755	26,838	30,705	35,569	33,358	26,215	21,240	15,970	11,035	7,285	17,065
1984	CPS	429	12,944	50,191	51,093	51,519	42,364	31,603	24,917	18,478	12,837	8,268	18,378
1985	CPS	394	4,071	9,764	13,785	16,277	14,666	11,126	8,822	6,515	4,517	2,938	6,856
1986	CPS	114	16,064	70,405	31,125	56,563	42,858	16,489	10,763	9,488	8,195	4,857	7,074
1987	CPS	0	7,865	14,913	16,976	11,722	7,096	4,039	3,806	3,151	2,960	567	5,859
1988	CPS	0	25,225	54,340	62,433	48,365	25,388	41,278	22,612	8,115	15,865	18,540	18,567
1989	CPS	1,272	32,139	48,795	48,563	67,047	53,652	23,263	33,721	17,783	8,462	11,396	30,199
1990	CPS	0	24,762	69,163	36,811	35,190	23,302	20,076	6,455	17,668	5,218	1,750	10,971
1991	CPS	2,930	36,503	116,630	108,448	51,067	53,172	34,292	20,410	8,156	29,302	6,096	15,914
1992	CPS	0	32,703	71,425	64,064	37,376	17,759	20,820	11,636	10,479	2,540	9,685	8,895
1993	CPS	2,263	30,874	56,345	80,432	70,671	32,323	14,616	17,470	10,308	7,506	1,343	26,017
1994	CPS	0	69,098	79,085	68,992	80,091	58,857	26,298	9,555	14,547	8,868	7,505	13,860
1995	CPS	327	30,098	77,194	64,613	43,494	33,911	26,328	12,146	4,928	4,611	3,487	5,290
1996	CPS	0	47,046	69,133	63,573	29,768	23,628	23,042	19,326	7,160	4,052	1,476	5,257
1997	CPS	0	21,935	65,799	64,725	37,415	32,436	23,817	21,358	13,821	7,745	6,814	9,736
1998	CPS	0	24,512	43,089	45,838	83,593	38,234	17,456	13,234	9,854	11,495	5,102	1,805
1999	CPS	0	33,850	47,795	37,203	45,231	38,259	23,210	10,543	10,529	7,189	2,409	8,127
2000	CPS	0	41,260	40,046	47,428	43,351	62,904	14,703	46,860	16,025	5,845	11,778	12,565
2001	CPS	1,945	26,678	72,699	52,872	37,405	34,308	39,185	41,369	24,797	7,260	10,518	35,391
2002	CPS	308	32,263	51,621	39,332	37,768	26,389	21,908	23,264	18,795	9,573	4,549	11,558
2003	CPS	0	11,935	54,207	54,894	52,895	40,402	26,387	16,012	23,294	15,214	8,739	12,640
2004	CPS	0	17572	56064	48649	58051	47988	33089	24906	13488	14049	8106	12487
2005	CPS	170	14,179	60,193	55,716	62,896	41,134	28,348	23,557	21,444	12,863	8,579	17,344
2006	CPS	326	16,575	81,702	67,524	63,269	59,841	39,987	29,515	23,379	11,066	9,366	23,565
2007	CPS	0	6,587	40,165	64,563	62,301	30,421	27,292	21,788	18,584	13,278	3,455	13,681
2008	CPS	0	35,266	44,769	44,264	66,449	60,954	38,777	39,077	17,338	12,063	7,356	15,571
2009	CPS	259	7,664	78,869	42,970	49,475	64,767	52,920	26,417	20,671	9,813	7,138	14,827
2010	CPS	864	6,165	25,703	49,576	30,378	18,466	24,422	16,963	7,332	6,573	3,641	7,744
2011	CPS	0	9,176	18,128	22,201	54,516	27,993	21,824	27,567	17,485	6,684	7,559	9,656
2012	CPS	0	17,407	38,175	27,928	28,219	75,652	35,172	24,615	33,925	20,458	7,160	16,138

Table 6. Total Catch-at-age input to the continuity VPA of Gulf of Mexico King Mackerel.

FishingYear	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1981	607,240	17,781	34,613	233,681	208,298	52,405	29,623	23,498	9,898	4,263	4,825	15,491
1982	257,856	57,953	191,470	162,737	219,546	158,348	69,655	18,978	18,578	21,647	7,011	185,719
1983	475,577	91,654	189,274	104,896	26,313	44,436	30,288	6,433	9,081	4,719	1,491	16,178
1984	1,488,541	20,293	57,178	217,980	126,139	35,634	48,374	25,272	4,692	906	1,836	16,901
1985	714,997	23,377	54,733	91,918	70,601	81,938	30,730	12,542	18,272	4,842	1,857	16,764
1986	818,149	36,845	210,302	80,828	35,078	54,787	39,664	12,431	2,982	6,872	577	14,869
1987	1,482,157	99,584	77,831	32,372	25,701	29,969	16,973	8,037	4,612	3,479	2,215	6,726
1988	1,697,316	46,875	97,388	88,417	64,224	31,403	68,958	29,778	6,058	13,579	13,292	33,580
1989	2,746,984	122,595	163,230	81,832	70,921	52,546	12,215	22,999	10,902	4,450	6,211	16,956
1990	2,026,503	101,316	158,574	101,679	70,824	34,129	36,735	7,138	18,270	8,218	1,574	18,018
1991	1,989,877	179,606	237,182	125,748	69,554	39,223	27,103	12,717	4,410	19,207	5,052	11,984
1992	1,445,427	64,535	197,906	179,420	101,516	53,561	46,338	20,703	33,510	9,177	16,641	24,423
1993	2,786,002	59,573	144,657	150,164	133,647	61,485	35,946	25,273	24,200	12,878	1,645	33,914
1994	3,083,134	124,123	152,137	122,409	159,205	115,774	67,746	40,528	24,196	19,517	38,935	33,374
1995	2,695,405	47,054	171,416	159,932	101,375	63,771	66,033	30,765	17,320	7,717	10,449	16,438
1996	1,346,504	85,220	237,119	153,294	85,058	51,949	35,155	34,274	27,127	12,596	2,734	40,225
1997	1,348,737	54,244	153,433	203,624	103,684	71,235	45,231	45,946	29,300	21,480	8,582	28,486
1998	1,214,668	59,394	120,370	155,940	171,750	72,547	40,669	24,915	17,718	20,549	9,256	7,289
1999	1,242,116	46,901	131,282	96,466	119,658	91,095	29,591	28,095	19,991	23,027	3,190	11,296
2000	1,084,923	64,442	135,085	176,958	98,624	64,216	29,002	33,786	8,886	14,092	10,749	17,593
2001	765,833	48,115	144,567	145,653	116,609	68,566	47,310	42,627	25,642	7,702	6,935	28,068
2002	632,793	69,706	201,720	128,530	110,550	72,263	39,256	29,967	29,859	15,189	7,290	21,537
2003	1,546,842	27,318	152,333	159,267	97,173	68,103	58,964	25,465	25,262	17,773	15,800	17,768
2004	2,889,854	33,584	230,269	129,867	105,756	54,077	42,900	37,411	10,935	22,691	6,762	14,043
2005	1,879,824	23,189	161,719	172,876	120,852	75,687	51,661	41,185	29,336	11,265	10,464	26,807
2006	912,368	19,855	176,135	201,077	156,636	106,437	57,965	42,397	28,008	16,522	8,889	28,551
2007	1,291,183	29,353	88,301	146,447	155,845	84,734	54,711	39,697	31,510	21,787	6,988	19,341
2008	495,900	76,312	192,188	103,580	138,623	115,079	71,087	60,942	26,935	18,316	10,034	18,667
2009	942,592	15,482	164,219	107,984	133,833	135,710	100,159	48,181	33,528	14,475	9,771	20,484
2010	877,109	13,053	75,976	120,660	101,694	54,466	65,855	37,249	18,175	12,580	6,413	12,676
2011	464,790	18,335	66,825	55,847	118,572	75,165	49,548	56,097	35,570	14,989	13,990	18,415
2012	770,655	28,549	72,571	63,699	58,713	128,293	66,398	42,257	55,283	32,315	14,111	26,369

Table 7. Continuity VPA Estimated Fishing Mortality-at-age of Gulf of Mexico King Mackerel.

FishingYear	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1981	0.21	0.02	0.05	0.29	0.36	0.34	0.31	0.29	0.15	0.18	0.04	0.04
1982	0.10	0.04	0.24	0.33	0.49	0.52	1.06	0.32	0.37	0.56	0.48	0.48
1983	0.42	0.07	0.19	0.21	0.08	0.17	0.17	0.24	0.25	0.15	0.06	0.06
1984	0.41	0.04	0.06	0.36	0.43	0.15	0.29	0.21	0.27	0.03	0.08	0.08
1985	0.27	0.01	0.15	0.13	0.19	0.56	0.19	0.11	0.22	0.47	0.09	0.09
1986	0.37	0.03	0.18	0.36	0.07	0.22	0.57	0.11	0.03	0.12	0.09	0.09
1987	0.51	0.10	0.08	0.04	0.19	0.07	0.10	0.21	0.05	0.05	0.05	0.05
1988	0.41	0.04	0.15	0.13	0.11	0.38	0.24	0.25	0.24	0.20	0.25	0.25
1989	0.57	0.07	0.19	0.18	0.15	0.12	0.24	0.11	0.13	0.27	0.13	0.13
1990	0.45	0.05	0.12	0.18	0.24	0.10	0.11	0.22	0.12	0.14	0.14	0.14
1991	0.60	0.09	0.18	0.14	0.19	0.20	0.11	0.05	0.20	0.18	0.11	0.11
1992	0.47	0.05	0.15	0.20	0.16	0.22	0.39	0.11	0.18	0.75	0.22	0.22
1993	0.61	0.04	0.16	0.17	0.23	0.14	0.22	0.38	0.18	0.09	0.28	0.28
1994	0.61	0.07	0.16	0.20	0.27	0.33	0.22	0.40	0.74	0.21	0.43	0.43
1995	0.63	0.02	0.14	0.27	0.26	0.17	0.31	0.14	0.29	0.53	0.16	0.16
1996	0.47	0.05	0.17	0.18	0.23	0.21	0.13	0.26	0.18	0.34	0.35	0.35
1997	0.38	0.04	0.13	0.22	0.18	0.30	0.27	0.25	0.36	0.20	0.40	0.40
1998	0.35	0.04	0.14	0.20	0.29	0.19	0.28	0.23	0.14	0.45	0.12	0.12
1999	0.37	0.03	0.11	0.16	0.23	0.25	0.11	0.31	0.29	0.26	0.11	0.11
2000	0.31	0.04	0.12	0.23	0.25	0.19	0.12	0.17	0.15	0.34	0.18	0.18
2001	0.20	0.03	0.13	0.18	0.23	0.28	0.21	0.25	0.18	0.18	0.27	0.27
2002	0.17	0.04	0.17	0.17	0.21	0.22	0.25	0.19	0.27	0.15	0.25	0.25
2003	0.29	0.01	0.11	0.20	0.19	0.19	0.28	0.25	0.24	0.25	0.23	0.23
2004	0.45	0.01	0.16	0.13	0.20	0.16	0.18	0.28	0.16	0.34	0.14	0.14
2005	0.43	0.01	0.08	0.18	0.17	0.22	0.22	0.25	0.36	0.24	0.25	0.25
2006	0.19	0.01	0.08	0.15	0.25	0.23	0.26	0.27	0.27	0.34	0.29	0.29
2007	0.20	0.01	0.06	0.09	0.16	0.21	0.18	0.28	0.33	0.33	0.23	0.23
2008	0.19	0.02	0.11	0.10	0.12	0.17	0.27	0.30	0.30	0.31	0.25	0.25
2009	0.23	0.01	0.07	0.08	0.18	0.17	0.22	0.29	0.26	0.25	0.27	0.27
2010	0.24	0.01	0.08	0.07	0.11	0.10	0.12	0.12	0.17	0.14	0.16	0.16
2011	0.26	0.01	0.04	0.08	0.09	0.11	0.12	0.14	0.16	0.19	0.22	0.22
2012	0.26	0.03	0.05	0.05	0.11	0.13	0.13	0.15	0.19	0.20	0.27	0.27

Table 8. Continuity VPA Estimated Abundance-at-age of Gulf of Mexico King Mackerel.

FishingYear	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1981	4,479,699	1,328,708	858,126	1,033,408	757,318	197,401	122,679	103,101	76,020	28,149	151,797	485,527
1982	3,901,263	1,685,975	994,760	642,598	620,151	429,312	115,049	74,844	64,626	54,668	19,784	522,244
1983	1,943,688	1,645,097	1,231,509	611,994	370,247	308,186	210,668	33,029	45,180	37,258	26,314	284,456
1984	6,132,216	596,103	1,171,212	799,463	396,880	277,325	213,147	147,084	21,693	29,584	27,027	247,868
1985	4,226,031	1,888,141	435,593	868,290	446,963	209,931	195,721	132,821	99,659	13,904	24,056	216,357
1986	3,666,077	1,498,838	1,415,240	293,489	613,587	300,003	99,018	134,307	99,322	66,853	7,290	187,164
1987	5,116,814	1,174,077	1,107,560	925,057	163,374	467,250	197,124	46,306	100,662	80,495	49,951	151,112
1988	7,094,488	1,425,577	806,287	800,168	712,074	109,751	356,871	147,915	31,302	80,130	64,526	162,425
1989	8,692,358	2,200,061	1,043,157	546,698	562,152	521,147	61,940	233,226	96,272	20,708	55,001	149,599
1990	7,778,887	2,280,457	1,566,294	674,643	365,059	393,309	380,787	40,257	173,516	70,718	13,359	152,355
1991	6,057,137	2,308,422	1,645,858	1,088,915	449,877	233,277	292,362	282,153	27,077	128,713	51,973	122,830
1992	5,367,498	1,542,781	1,599,295	1,082,280	760,192	303,307	156,314	217,629	223,657	18,667	90,722	132,663
1993	8,398,046	1,563,413	1,116,943	1,080,237	707,255	526,846	200,937	87,646	162,601	156,844	7,386	151,722
1994	9,266,989	2,122,459	1,136,930	748,777	731,563	455,128	377,413	133,917	50,160	114,175	120,153	102,632
1995	7,894,093	2,336,662	1,505,983	757,883	490,840	452,075	269,777	251,323	74,919	20,144	78,216	122,595
1996	4,975,254	1,948,477	1,735,674	1,030,327	464,918	308,170	313,935	163,785	181,548	47,006	9,930	145,579
1997	5,963,037	1,444,982	1,407,434	1,152,744	688,827	301,675	206,378	228,209	105,425	127,381	28,059	92,809
1998	5,734,516	1,898,314	1,051,508	968,852	742,207	466,922	183,744	130,049	148,530	61,689	87,531	68,675
1999	5,628,136	1,877,757	1,391,698	718,795	637,273	449,542	318,233	115,428	85,789	108,286	33,189	117,088
2000	5,790,131	1,811,234	1,386,914	975,987	489,851	410,774	287,303	236,806	70,738	53,684	70,074	114,272
2001	6,007,986	1,986,122	1,321,116	968,889	624,362	309,820	279,613	211,719	166,707	51,164	32,312	130,303
2002	5,890,338	2,292,623	1,468,253	908,950	646,424	403,010	192,820	188,798	137,796	116,303	36,001	105,975
2003	8,741,003	2,324,488	1,682,536	974,143	613,630	426,338	266,004	124,213	130,163	88,268	83,949	94,063
2004	11,173,105	3,056,552	1,743,572	1,185,563	638,562	411,649	288,900	167,024	80,431	86,048	58,026	120,062
2005	7,486,670	3,328,765	2,294,711	1,164,952	833,918	424,236	289,455	200,470	105,286	57,418	51,696	131,958
2006	7,379,517	2,265,914	2,510,693	1,657,436	779,229	569,449	280,359	193,019	129,730	61,540	38,015	121,665
2007	10,263,924	2,834,365	1,705,520	1,814,139	1,148,483	493,065	371,975	179,805	122,429	83,194	36,706	101,225
2008	4,039,041	3,927,814	2,129,458	1,259,963	1,322,550	793,728	328,747	258,592	113,864	73,914	50,119	92,904
2009	6,543,680	1,553,593	2,919,993	1,501,012	916,878	950,596	548,387	208,029	160,278	70,889	45,472	94,985
2010	5,729,352	2,426,809	1,167,734	2,145,672	1,106,004	625,241	658,669	363,621	129,703	103,760	46,418	91,414
2011	2,821,084	2,091,358	1,833,756	849,004	1,611,034	807,713	464,578	485,963	269,263	92,101	75,780	99,387
2012	4,782,543	1,008,585	1,574,127	1,379,495	630,242	1,203,042	595,827	339,957	354,122	193,167	63,781	118,758

Table 9. Continuity VPA Estimated Spawning Stock Biomass (SSB in million eggs) and Recruitment of Gulf of Mexico King Mackerel.

Fishing Year	SSB	Recruits
1981	2,149	4,479,699
1982	2,038	3,901,263
1983	1,511	1,943,688
1984	1,540	6,132,216
1985	1,450	4,226,031
1986	1,473	3,666,077
1987	1,515	5,116,814
1988	1,642	7,094,488
1989	1,639	8,692,358
1990	1,743	7,778,887
1991	1,872	6,057,137
1992	2,006	5,367,498
1993	1,997	8,398,046
1994	1,968	9,266,989
1995	1,836	7,894,093
1996	1,874	4,975,254
1997	1,875	5,963,037
1998	1,816	5,734,516
1999	1,824	5,628,136
2000	1,851	5,790,131
2001	1,884	6,007,986
2002	1,888	5,890,338
2003	1,938	8,741,003
2004	2,036	11,173,105
2005	2,246	7,486,670
2006	2,442	7,379,517
2007	2,549	10,263,924
2008	2,782	4,039,041
2009	2,994	6,543,680
2010	3,052	5,729,352
2011	3,266	2,821,084
2012	3,354	4,782,543

Table 10. Revised life-history assumptions for the Base VPA.

Age	0	1	2	3	4	5	6	7	8	9	10	11+
M	0.66	0.25	0.22	0.22	0.20	0.19	0.18	0.17	0.17	0.16	0.16	0.16
Maturity	0.00	0.62	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fecundity	0.00	0.16	0.25	0.35	0.46	0.58	0.70	0.83	0.95	1.06	1.17	1.60

Table 11. Indices of Abundance of Gulf of Mexico King Mackerel used in the Base VPA.

	Headboat		Logbook		SEAMAP_Plankton		SEAMAP_Trawl	
units	number		biomass		number		number	
GLM	delta-lognormal		delta-lognormal		delta-lognormal		delta-lognormal	
ages	1-6		1-11		1-11		0	
	Index	CV	Index	CV	Index	CV	Index	CV
1972	-	-	-	-	-	-	3.496	0.365
1973	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	1.295	0.574
1975	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	0.067	1.096
1977	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	0.862	0.666
1979	-	-	-	-	-	-	1.108	0.475
1980	-	-	-	-	-	-	0.065	1.097
1981	-	-	-	-	-	-	0.200	0.799
1982	-	-	-	-	-	-	0.095	1.099
1983	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	0.824	0.578
1985	-	-	-	-	-	-	0.274	0.526
1986	0.699	0.186	-	-	0.115	0.530	0.508	0.795
1987	0.652	0.181	-	-	0.376	0.318	0.062	1.100
1988	0.780	0.199	-	-	0.590	0.433	0.626	0.367
1989	0.809	0.191	-	-	0.801	0.334	0.409	0.570
1990	0.533	0.176	-	-	0.656	0.327	1.451	0.262
1991	1.336	0.160	-	-	0.704	0.314	0.218	0.439
1992	1.225	0.158	-	-	0.628	0.233	0.296	0.469
1993	0.846	0.155	-	-	1.222	0.205	2.346	0.228
1994	1.162	0.138	-	-	1.013	0.220	0.871	0.350
1995	1.274	0.138	-	-	1.942	0.196	0.609	0.435
1996	1.394	0.145	-	-	0.741	0.261	0.596	0.367
1997	1.157	0.167	-	-	1.292	0.202	1.152	0.300
1998	1.038	0.149	1.113	0.085	-	-	1.003	0.291
1999	0.945	0.173	0.895	0.075	0.918	0.216	0.992	0.292
2000	0.874	0.155	0.835	0.078	0.912	0.269	0.506	0.409
2001	0.669	0.164	0.845	0.076	1.537	0.201	1.428	0.283
2002	0.721	0.153	0.843	0.075	1.417	0.212	1.239	0.313
2003	1.002	0.154	0.849	0.083	1.054	0.217	2.486	0.196
2004	0.666	0.165	0.854	0.088	1.447	0.208	2.185	0.224
2005	1.008	0.163	0.927	0.103	-	-	1.449	0.214
2006	1.288	0.148	0.911	0.101	1.155	0.250	1.587	0.256
2007	1.179	0.151	1.015	0.092	1.403	0.216	2.650	0.197
2008	1.095	0.167	0.976	0.097	-	-	0.229	0.573
2009	1.594	0.135	1.120	0.091	0.823	0.237	1.501	0.231
2010	0.941	0.171	1.335	0.110	1.133	0.250	1.152	0.280
2011	1.142	0.150	1.043	0.120	1.266	0.249	0.311	0.660
2012	0.971	0.138	1.146	0.105	0.855	0.257	0.853	0.440

Table 12. Commercial Handline Partial Catch-at-age Input to the Base VPA of Gulf of Mexico King Mackerel.

FishingYear	Fleet	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1986	HL	0	2,212	6,660	8,031	19,053	15,657	6,465	4,705	4,043	3,903	2,571	4,596
1987	HL	0	401	1,898	5,817	5,895	4,624	3,422	3,069	4,206	2,974	710	10,527
1988	HL	0	1,218	5,779	8,246	10,415	5,748	11,786	7,827	2,490	5,916	6,837	9,868
1989	HL	374	10,154	15,374	14,340	19,447	17,492	6,877	11,150	6,466	2,716	5,058	15,139
1990	HL	0	3,333	25,195	12,996	10,607	6,577	6,249	3,552	7,791	3,582	1,085	18,526
1991	HL	950	14,152	33,127	24,143	11,705	13,159	12,208	6,925	2,822	12,482	2,606	9,675
1992	HL	0	19,053	58,769	52,979	32,945	16,461	18,166	9,036	9,059	2,335	7,495	7,192
1993	HL	499	22,188	48,674	53,493	36,473	16,239	7,229	9,010	4,885	4,125	651	13,655
1994	HL	0	25,356	40,562	36,641	40,742	24,222	10,449	3,901	5,851	3,463	2,667	5,196
1995	HL	62	12,515	37,761	30,978	21,136	17,459	14,925	7,463	3,106	2,858	2,611	3,631
1996	HL	0	50,253	47,636	34,321	12,784	8,947	8,770	7,427	2,723	1,698	495	1,768
1997	HL	0	20,324	64,731	56,770	25,505	17,723	10,029	9,806	5,959	4,136	3,536	3,824
1998	HL	0	26,167	49,198	35,596	54,826	21,287	6,978	4,610	2,700	4,195	1,599	541
1999	HL	0	39,052	69,300	39,740	40,929	29,534	17,001	8,487	8,514	5,843	1,137	4,892
2000	HL	0	22,932	31,693	37,452	31,919	28,690	11,353	19,744	7,712	5,923	4,257	3,990
2001	HL	1390	17,386	68,971	40,862	29,345	18,291	13,569	11,473	7,678	1,677	2,581	7,391
2002	HL	294	34,916	57,056	33,093	22,885	12,677	9,620	9,542	7,054	3,488	1,626	3,683
2003	HL	0	14,927	55,875	37,426	29,366	18,390	12,365	6,593	7,591	5,243	3,306	4,539
2004	HL	0	15,762	56,661	32,688	29,718	22,128	12,675	8,832	5,493	4,892	2,485	2,774
2005	HL	166	8,383	40,126	34,009	33,567	19,676	13,191	10,704	8,106	5,066	4,053	7,185
2006	HL	41	4,826	36,712	37,929	36,753	31,473	18,109	13,736	10,663	4,331	3,754	7,899
2007	HL	0	1,556	16,014	43,280	44,950	24,989	19,543	13,263	10,607	7,836	2,751	4,971
2008	HL	0	10274	20570	25539	43383	40175	23945	23883	10316	5850	2831	2893
2009	HL	184	5,454	60,753	34,223	41,231	48,371	33,222	16,361	11,039	4,584	2,556	5,506
2010	HL	0	1,618	14,166	44,831	32,579	20,240	26,453	15,854	6,718	5,325	2,158	4,089
2011	HL	0	2,529	10,364	15,190	44,198	26,231	20,247	24,752	15,172	5,556	6,286	7,497
2012	HL	0	1,641	11,436	15,347	15,347	41,799	22,921	12,745	19,656	11,121	4,541	9,148

Table 13. Recreational Headboat Partial Catch-at-age Input to the Base VPA of Gulf of Mexico King Mackerel.

FishingYear	Fleet	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1986	HB	0	259	1,063	1,056	2,223	1,547	527	325	322	314	213	257
1987	HB	0	338	1,149	2,078	1,564	1,032	585	523	435	454	65	742
1988	HB	0	515	1,453	1,848	1,500	816	1,195	623	235	400	482	367
1989	HB	26	201	1,057	1,963	2,490	1,857	795	1,006	549	249	305	771
1990	HB	0	470	2,391	1,811	1,810	969	769	216	602	221	14	404
1991	HB	56	1,129	5,100	3,802	1,540	1,425	834	515	214	619	114	271
1992	HB	0	640	4,419	4,940	2,852	1,315	1,322	694	678	175	505	543
1993	HB	59	627	3,285	5,105	3,767	1,630	784	911	492	382	61	1,338
1994	HB	0	2,742	4,218	3,548	3,753	2,302	992	380	535	320	207	380
1995	HB	27	1,496	4,651	4,585	3,336	2,553	1,811	861	337	312	261	321
1996	HB	0	2,091	5,232	5,265	2,399	1,786	1,825	1,604	600	386	127	512
1997	HB	0	946	3,574	3,793	2,078	1,783	1,369	1,381	1,103	1,043	1,128	1,224
1998	HB	0	500	1,473	1,916	4,594	2,300	987	790	578	755	323	445
1999	HB	0	990	2812	3338	4071	2812	1973	882	1246	880	205	922
2000	HB	0	1316	1685	2498	2238	2025	828	1391	526	291	375	316
2001	HB	37	527	2791	2295	2143	1600	1328	1255	834	199	279	795
2002	HB	11	1711	4732	4244	3555	2018	1552	1620	1077	525	233	519
2003	HB	0	370	2594	2792	2661	1643	1284	672	791	511	324	439
2004	HB	0	638	3619	3594	4243	3160	1826	1226	854	798	376	443
2005	HB	5	502	3991	4500	4808	3043	1912	1489	1111	677	518	779
2006	HB	0	389	3802	4061	4149	3406	2062	1376	1117	518	358	887
2007	HB	0	240	1507	4024	4077	2056	1579	1203	843	555	186	490
2008	HB	0	1567	2387	1941	2813	2666	1701	1644	839	568	540	591
2009	HB	9	428	3759	2076	2408	3239	2614	1340	1073	435	302	754
2010	HB	0	91	1182	4036	2998	1859	2217	1276	506	455	162	373
2011	HB	0	389	1376	1638	3812	2252	1595	2172	1217	478	565	697
2012	HB	0	158	1030	1434	1375	3344	1855	1028	1537	925	367	780

Table 14. Total Catch-at-age input to the Base VPA of Gulf of Mexico King Mackerel.

FishingYear	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1986	741,465	35,491	145,260	56,439	100,337	75,357	28,360	18,930	16,951	15,216	9,375	14,562
1987	1,451,856	16,492	23,564	30,132	22,651	15,005	9,387	8,659	8,917	7,351	1,554	19,488
1988	1,734,784	28,820	66,667	78,669	65,418	34,715	58,880	33,807	11,769	24,141	28,156	31,584
1989	2,789,480	50,240	80,082	81,017	104,948	83,895	36,492	51,469	28,522	13,102	19,008	53,046
1990	2,089,026	38,837	126,766	64,864	58,515	38,366	33,895	12,832	32,626	10,984	3,475	35,868
1991	2,122,547	61,600	191,847	162,016	72,780	74,434	51,114	30,014	12,101	45,091	9,375	27,396
1992	1,782,387	85,370	233,222	185,202	97,516	45,091	49,132	25,592	24,654	5,955	20,645	19,347
1993	3,077,082	74,157	138,661	174,209	133,376	59,195	26,518	32,008	18,174	13,960	2,363	46,985
1994	3,237,865	135,909	172,438	140,634	155,618	100,782	44,284	16,258	24,416	14,877	12,101	22,509
1995	2,978,007	56,341	164,809	140,131	95,577	75,313	59,187	28,732	11,490	10,828	9,060	13,042
1996	1,341,289	154,155	182,492	148,327	61,888	46,176	45,346	37,426	13,656	7,998	2,769	9,609
1997	1,472,884	57,847	174,880	165,919	84,472	67,114	42,586	40,219	26,123	16,870	13,843	17,940
1998	1,605,493	64,146	130,237	112,521	194,321	81,602	29,996	20,611	12,251	18,103	7,218	3,009
1999	1,636,573	87,736	142,154	93,371	101,623	76,249	45,179	22,404	23,981	16,105	3,400	14,242
2000	1,548,068	74,018	90,161	109,000	97,939	91,161	36,121	64,218	24,918	18,969	17,084	13,733
2001	1,260,143	42,806	159,673	101,140	80,300	58,301	49,630	50,573	31,057	9,821	11,266	35,746
2002	1,340,119	82,574	143,697	95,753	75,663	46,800	36,492	37,229	29,831	14,864	7,009	16,442
2003	2,635,729	30,459	136,616	117,835	99,952	67,324	47,419	26,522	32,115	21,840	13,195	18,650
2004	4,016,258	44,820	165,446	105,351	105,548	81,167	51,272	37,788	21,668	20,476	11,164	15,799
2005	2,332,040	28,892	133,671	111,596	113,114	69,413	46,982	38,291	32,576	19,162	14,045	27,080
2006	1,184,381	23,406	137,650	127,198	117,763	100,552	61,421	45,186	34,839	15,913	13,353	30,974
2007	1,103,436	9,439	69,697	135,621	133,781	67,518	52,730	37,988	30,319	21,948	7,520	19,127
2008	833,918	57,755	101,765	93,296	137,147	125,539	75,463	73,841	31,910	19,807	12,146	19,200
2009	822,858	15,602	167,118	95,030	111,718	134,797	97,762	49,281	34,560	15,418	9,674	22,111
2010	570,971	10,293	50,212	118,216	82,808	51,967	66,290	40,532	17,690	14,015	6,695	13,627
2011	483,338	14,124	43,248	48,858	120,659	69,834	50,918	59,775	36,253	13,533	14,875	18,456
2012	491,741	16,829	61,417	67,470	59,477	132,358	71,152	39,079	55,566	31,494	12,409	25,732

Table 15. Base VPA Estimated Fishing Mortality-at-age of Gulf of Mexico King Mackerel.

FishingYear	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1986	0.38	0.04	0.19	0.21	0.15	0.31	0.32	0.12	0.09	0.66	0.11	0.11
1987	0.70	0.02	0.03	0.05	0.12	0.03	0.06	0.15	0.08	0.05	0.12	0.12
1988	0.52	0.03	0.09	0.14	0.16	0.28	0.16	0.28	0.30	0.28	0.26	0.26
1989	0.70	0.03	0.13	0.16	0.28	0.32	0.52	0.19	0.39	0.60	0.36	0.36
1990	0.50	0.02	0.11	0.15	0.16	0.15	0.20	0.34	0.17	0.25	0.29	0.29
1991	0.67	0.03	0.16	0.21	0.26	0.32	0.31	0.27	0.60	0.37	0.33	0.33
1992	0.61	0.07	0.17	0.24	0.19	0.25	0.35	0.25	0.35	0.65	0.27	0.27
1993	0.71	0.06	0.15	0.18	0.27	0.17	0.22	0.40	0.27	0.33	0.56	0.56
1994	0.70	0.08	0.20	0.23	0.25	0.34	0.18	0.20	0.59	0.35	0.51	0.51
1995	0.71	0.03	0.14	0.25	0.24	0.19	0.33	0.16	0.21	0.54	0.35	0.35
1996	0.49	0.09	0.13	0.18	0.17	0.18	0.16	0.36	0.11	0.21	0.24	0.24
1997	0.52	0.05	0.15	0.17	0.15	0.28	0.24	0.20	0.43	0.18	0.63	0.63
1998	0.52	0.05	0.14	0.14	0.32	0.21	0.19	0.17	0.08	0.59	0.10	0.10
1999	0.51	0.06	0.15	0.15	0.18	0.20	0.16	0.20	0.30	0.15	0.20	0.20
2000	0.50	0.05	0.09	0.17	0.23	0.24	0.13	0.36	0.35	0.39	0.22	0.22
2001	0.36	0.03	0.15	0.14	0.19	0.21	0.20	0.27	0.29	0.22	0.40	0.40
2002	0.43	0.05	0.14	0.13	0.15	0.16	0.19	0.22	0.24	0.21	0.23	0.23
2003	0.58	0.02	0.11	0.16	0.20	0.19	0.23	0.20	0.28	0.27	0.27	0.27
2004	0.74	0.02	0.15	0.12	0.22	0.25	0.21	0.29	0.24	0.28	0.20	0.20
2005	0.69	0.01	0.09	0.15	0.18	0.21	0.22	0.23	0.42	0.33	0.31	0.31
2006	0.36	0.02	0.08	0.12	0.23	0.23	0.29	0.32	0.32	0.35	0.38	0.38
2007	0.23	0.01	0.07	0.11	0.17	0.20	0.18	0.29	0.36	0.33	0.27	0.27
2008	0.46	0.02	0.08	0.12	0.16	0.24	0.35	0.40	0.41	0.41	0.30	0.30
2009	0.29	0.02	0.09	0.10	0.21	0.23	0.30	0.40	0.32	0.34	0.34	0.34
2010	0.28	0.01	0.08	0.08	0.12	0.14	0.17	0.19	0.24	0.20	0.23	0.23
2011	0.35	0.01	0.04	0.10	0.11	0.14	0.19	0.22	0.25	0.27	0.32	0.32
2012	0.21	0.02	0.08	0.08	0.18	0.17	0.21	0.21	0.31	0.34	0.41	0.41

Table 16. Base VPA Estimated Abundance-at-age of Gulf of Mexico King Mackerel.

FishingYear	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1986	3,142,836	1,159,752	954,118	330,262	791,823	311,546	112,966	180,089	215,258	33,665	95,310	148,043
1987	3,784,558	1,111,519	872,001	636,271	214,777	557,878	189,541	68,596	134,598	166,075	14,779	185,330
1988	5,720,040	968,837	851,141	678,743	483,706	155,425	447,725	149,758	49,945	105,384	134,746	151,151
1989	7,295,129	1,765,169	729,184	623,553	474,550	337,089	97,148	320,357	95,453	31,385	67,625	188,723
1990	7,113,704	1,873,433	1,330,519	513,759	428,187	294,164	202,962	48,097	223,184	54,508	14,757	152,318
1991	5,726,516	2,240,671	1,424,859	954,667	354,470	297,855	208,509	138,685	28,862	158,434	36,353	106,233
1992	5,172,102	1,514,068	1,690,844	972,467	621,842	224,750	179,066	127,726	89,572	13,342	93,630	87,743
1993	7,937,237	1,455,239	1,104,116	1,149,058	615,561	421,308	145,075	104,962	84,361	53,064	5,925	117,811
1994	8,501,089	2,011,173	1,068,147	762,446	766,916	384,041	294,796	97,054	59,354	54,562	32,402	60,271
1995	7,747,395	2,191,372	1,446,875	703,600	486,672	487,909	226,562	205,925	67,008	27,859	32,839	47,272
1996	4,630,544	1,979,504	1,657,077	1,014,167	439,942	312,462	335,296	135,490	147,433	46,022	13,827	47,981
1997	4,858,624	1,470,849	1,406,215	1,167,072	681,707	304,445	216,582	238,775	80,145	111,875	31,862	41,292
1998	5,293,944	1,499,773	1,094,630	972,588	788,724	482,016	191,087	142,176	164,654	43,797	79,814	33,272
1999	5,451,466	1,633,730	1,111,620	762,325	680,180	471,132	324,753	132,308	101,086	127,687	20,757	86,946
2000	5,258,750	1,693,414	1,195,223	765,365	528,525	465,359	320,586	230,124	91,129	63,375	93,986	75,551
2001	5,589,958	1,653,903	1,253,749	878,709	517,078	344,583	302,374	234,872	135,531	54,136	36,602	116,136
2002	5,113,822	2,016,635	1,250,403	863,802	614,983	351,037	232,188	207,401	151,932	85,966	37,101	87,034
2003	7,974,962	1,718,664	1,497,939	875,319	607,820	435,320	247,903	160,727	140,927	100,904	59,586	84,220
2004	10,136,565	2,317,694	1,311,704	1,080,226	597,422	407,651	299,040	163,937	111,336	89,550	65,916	93,283
2005	6,190,742	2,512,730	1,765,594	905,161	772,911	394,125	263,697	203,127	103,782	74,118	57,498	110,862
2006	5,293,123	1,612,551	1,931,488	1,297,607	626,909	530,926	263,110	177,516	136,357	57,846	45,566	105,696
2007	7,288,710	1,915,525	1,235,258	1,427,180	927,879	407,299	348,086	163,955	108,498	83,224	34,688	88,227
2008	3,023,886	2,997,715	1,483,504	929,082	1,024,334	639,179	275,707	242,749	103,615	63,862	50,769	80,254
2009	4,345,724	988,518	2,283,816	1,099,696	662,374	715,091	415,019	161,777	137,436	58,308	36,253	82,860
2010	3,161,705	1,674,307	756,130	1,683,625	797,723	441,731	469,402	257,820	91,529	84,386	35,533	72,323
2011	2,223,249	1,237,043	1,294,891	561,978	1,245,609	578,470	318,209	331,727	180,427	61,045	59,019	73,227
2012	3,553,776	814,150	950,979	1,000,533	407,400	911,025	415,102	219,451	225,197	119,076	39,585	82,086

Table 17. Base VPA estimated spawning stock biomass (SSB, million eggs) and recruitment of Gulf of Mexico King Mackerel.

FishingYear	SSB	Recruits
1986	1,812	3,142,836
1987	1,763	3,784,558
1988	1,839	5,720,040
1989	1,809	7,295,129
1990	1,751	7,113,704
1991	1,887	5,726,516
1992	1,879	5,172,102
1993	1,848	7,937,237
1994	1,822	8,501,089
1995	1,839	7,747,395
1996	1,946	4,630,544
1997	2,017	4,858,624
1998	1,985	5,293,944
1999	2,003	5,451,466
2000	2,024	5,258,750
2001	2,019	5,589,958
2002	2,027	5,113,822
2003	2,107	7,974,962
2004	2,191	10,136,565
2005	2,331	6,190,742
2006	2,403	5,293,123
2007	2,389	7,288,710
2008	2,551	3,023,886
2009	2,529	4,345,724
2010	2,426	3,161,705
2011	2,449	2,223,249
2012	2,358	3,553,776

5. Figures

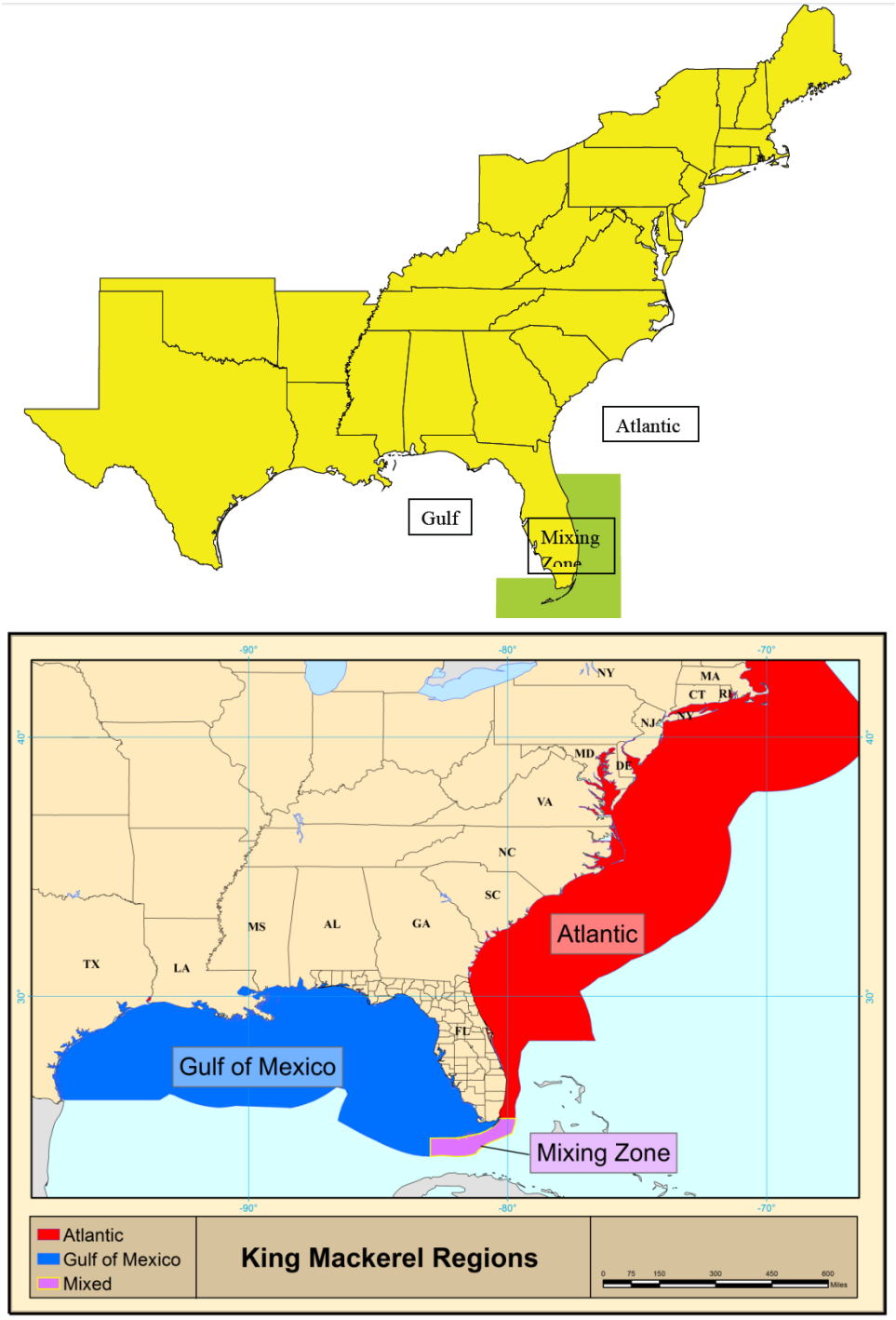
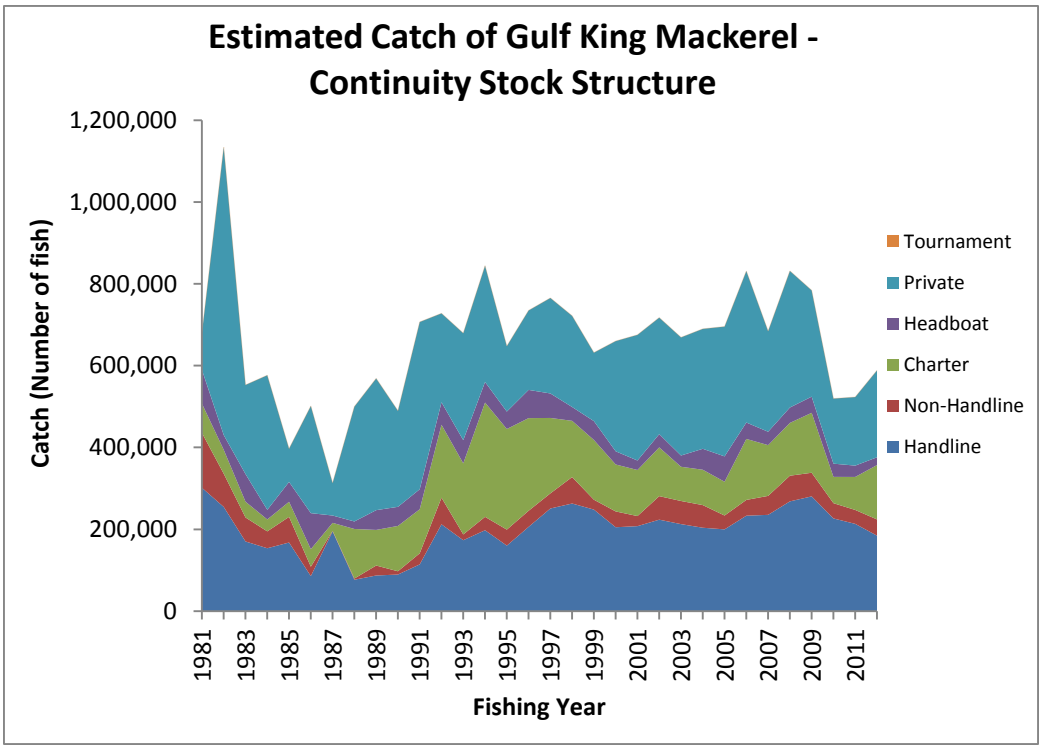


Figure 1. Stock distribution assumptions for the continuity VPA (upper figure) and base VPA (lower figure).



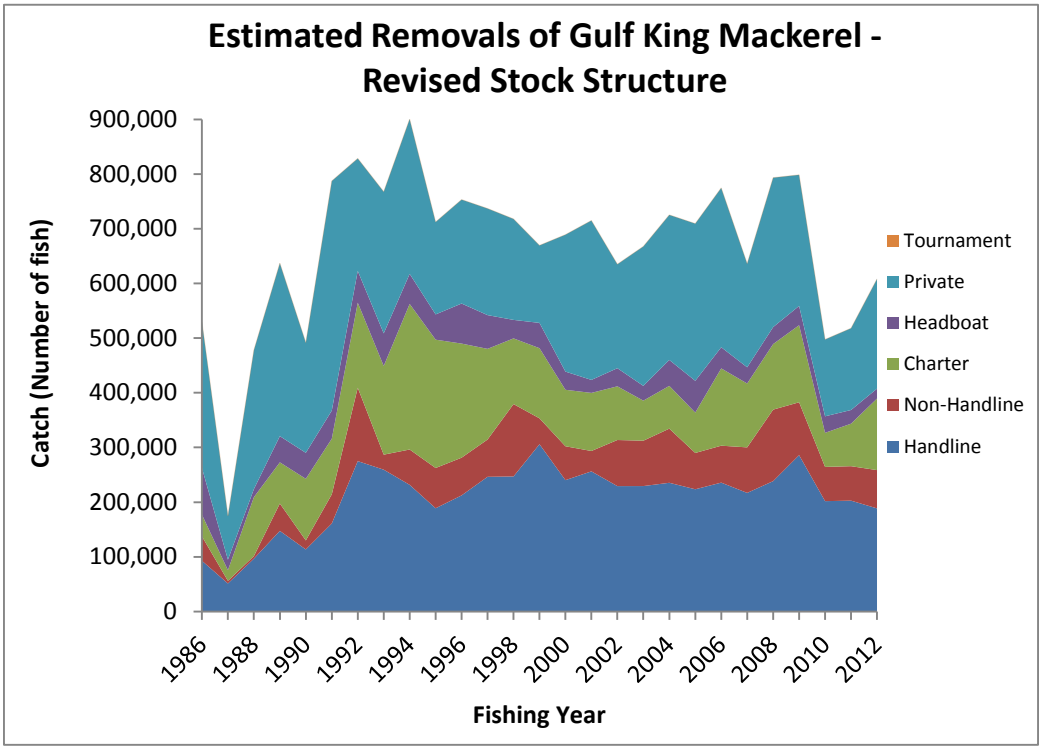


Figure 2. Estimated removals (catch plus discard mortalities) of Gulf of Mexico King Mackerel by fishery for the continuity VPA (upper figure) and base VPA (lower figure).

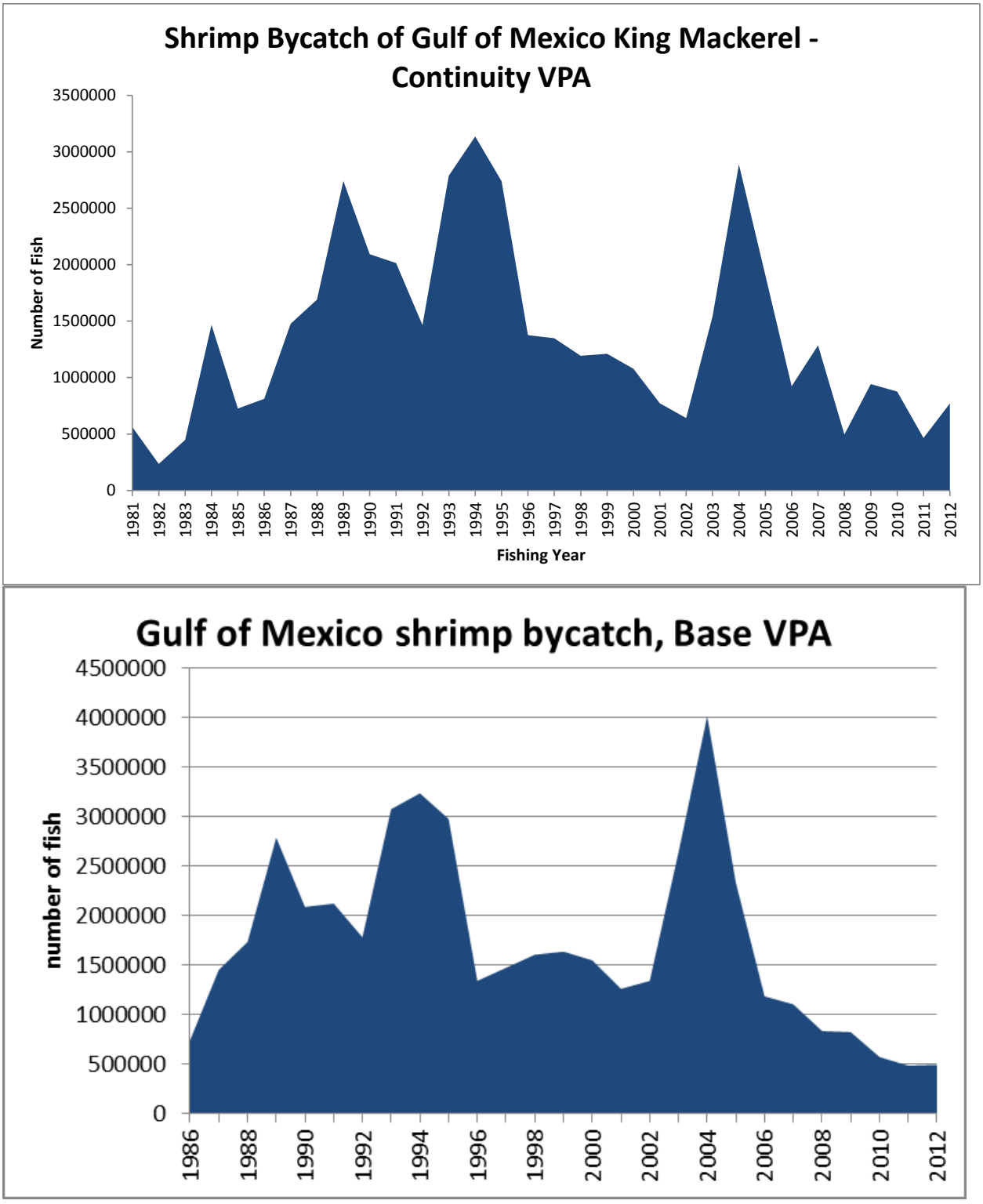


Figure 3. Shrimp fishery bycatch of age-0 Gulf of Mexico King Mackerel from the shrimp fishery, estimated in numbers of fish for the continuity VPA (upper figure) and base VPA (lower figure).

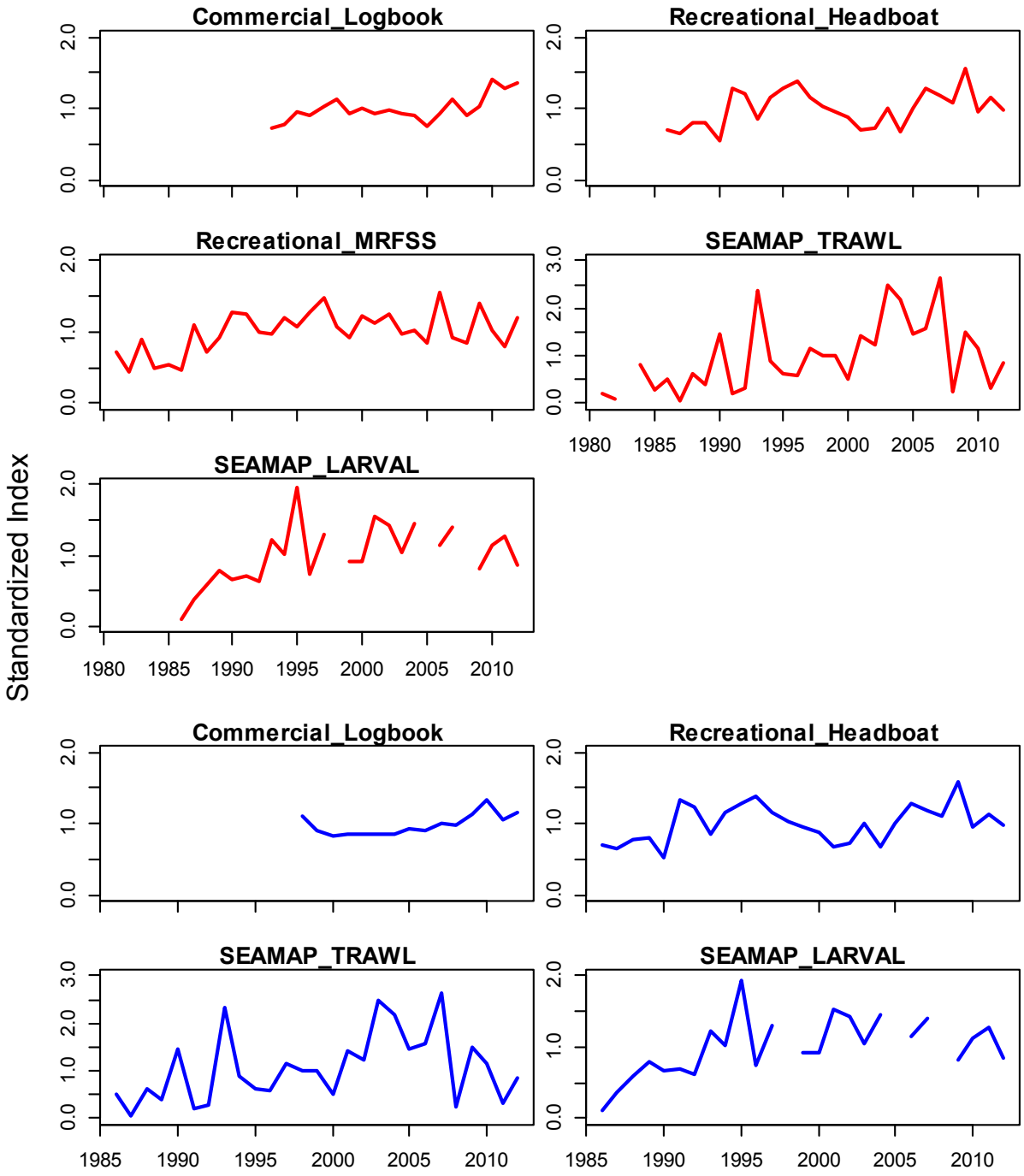


Figure 4. Indices of abundance of Gulf of Mexico King Mackerel used in the continuity VPA (left panels with indices shown in blue) and the base VPA (right panels with indices shown in red).

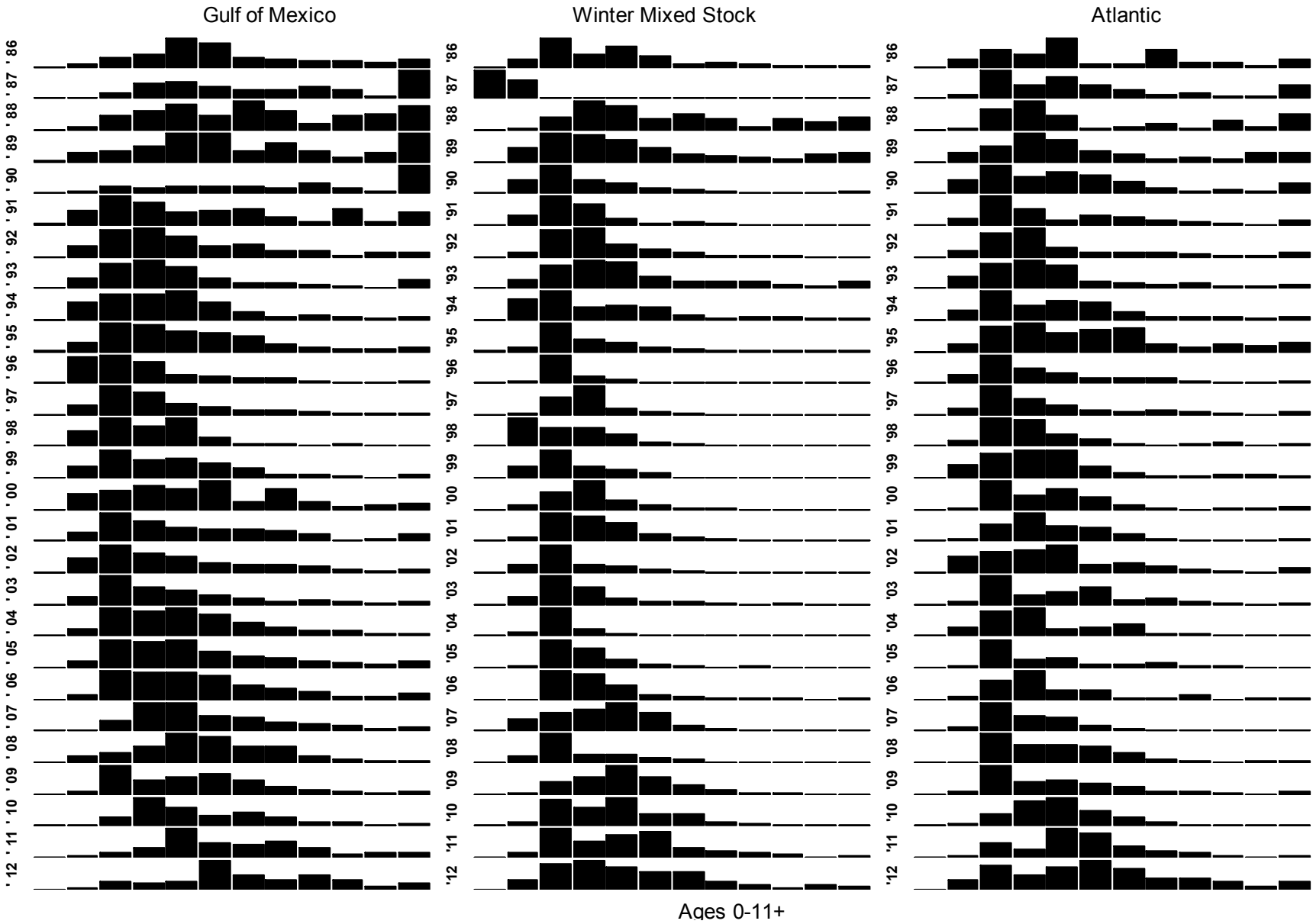


Figure 5. Age frequency distribution of King Mackerel caught in the commercial handline fleet, continuity model.

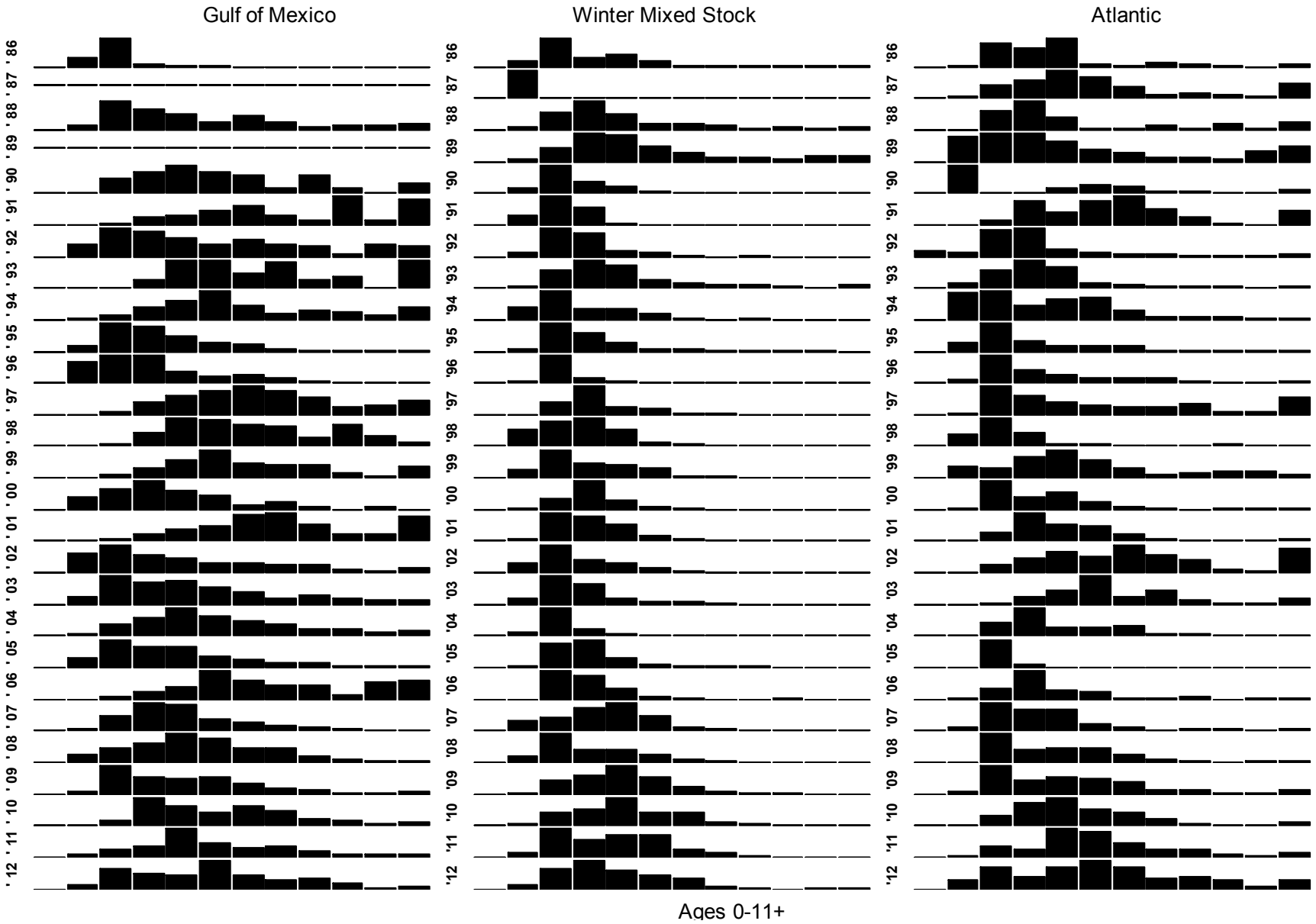


Figure 6. Age frequency distribution of King Mackerel caught in the other commercial fleets combined, continuity model.

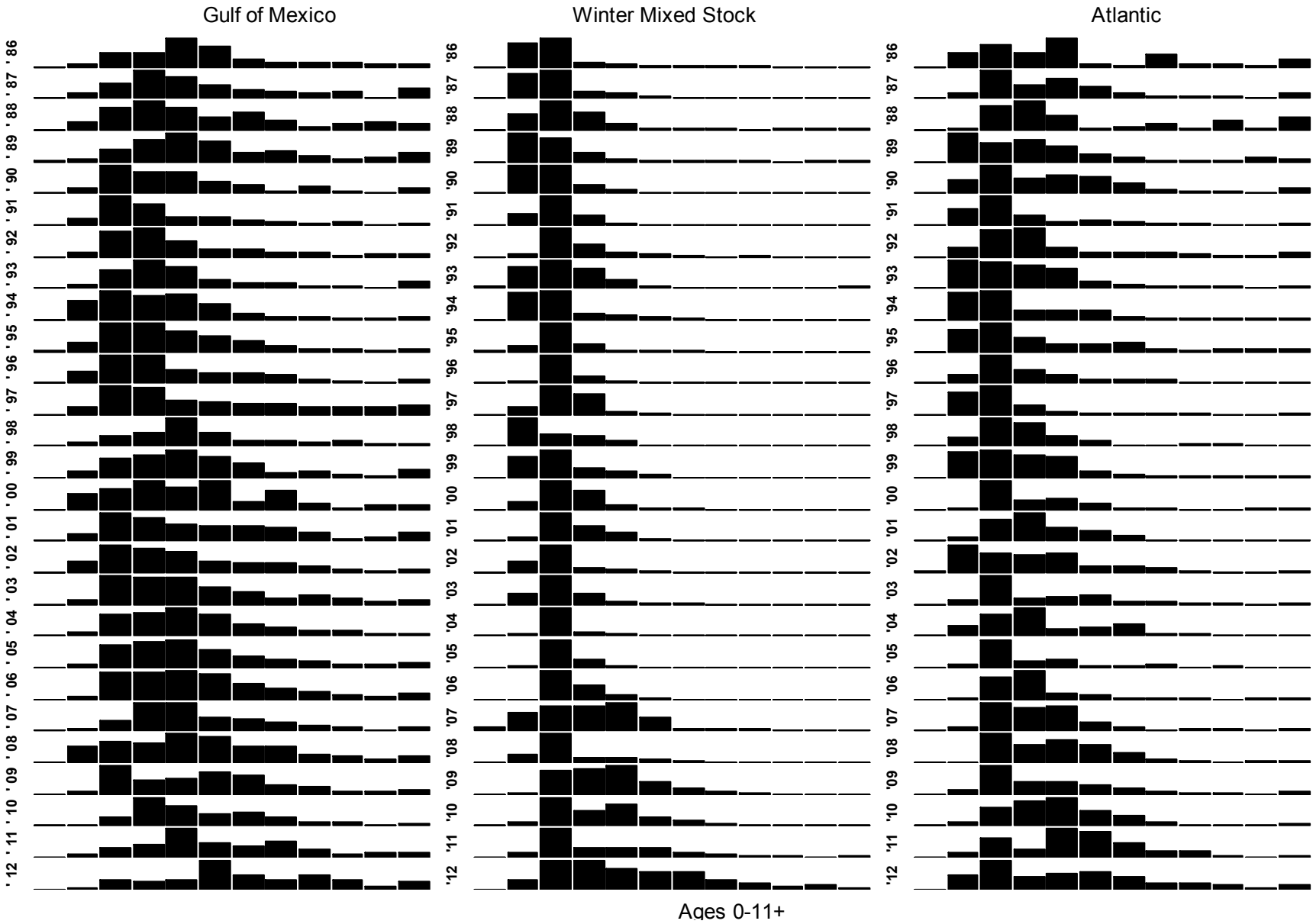


Figure 7. Age frequency distribution of King Mackerel caught in the recreational headboat fleet, continuity model.

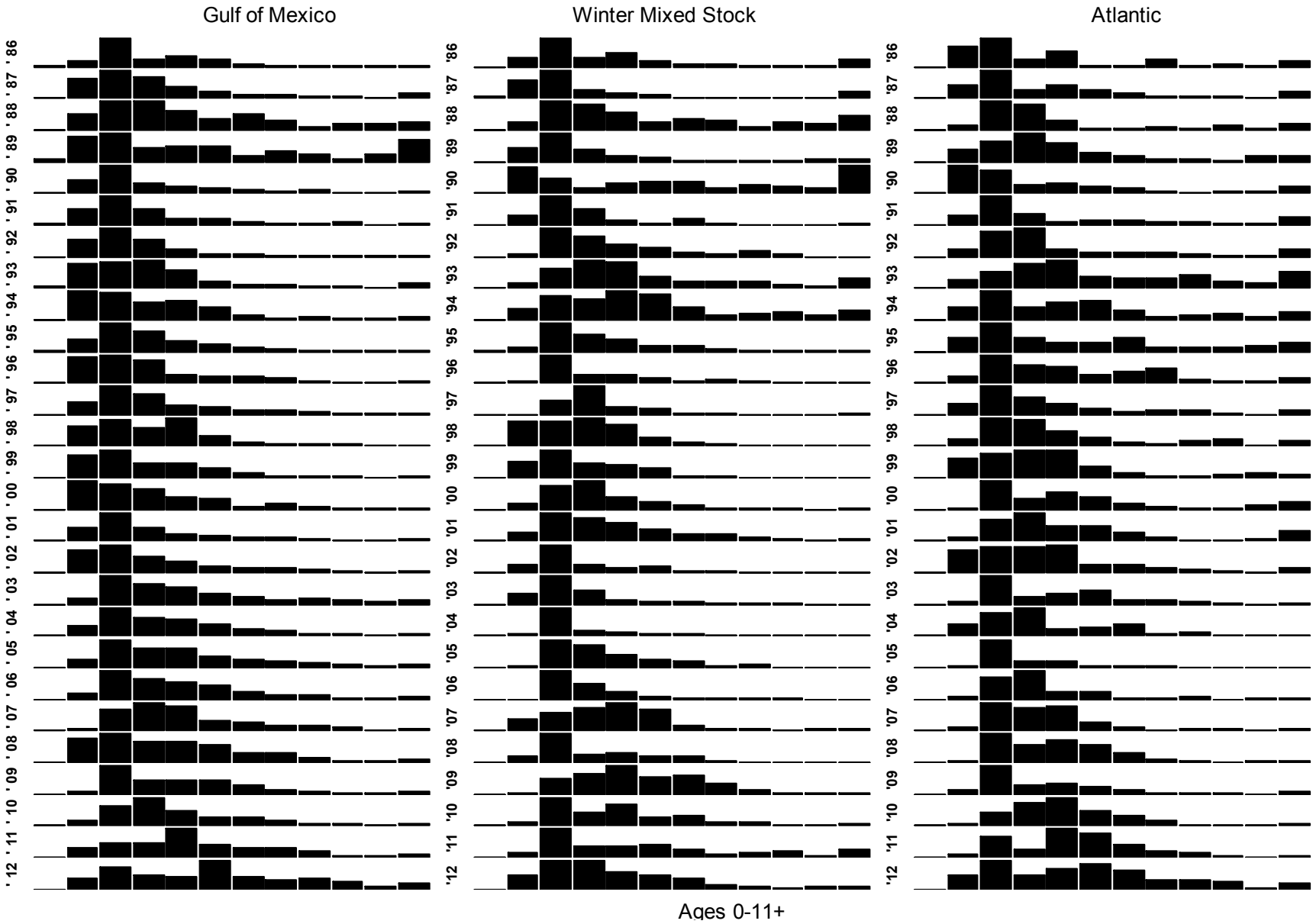


Figure 8. Age frequency distribution of King Mackerel caught in the recreational charter fleet, continuity model.

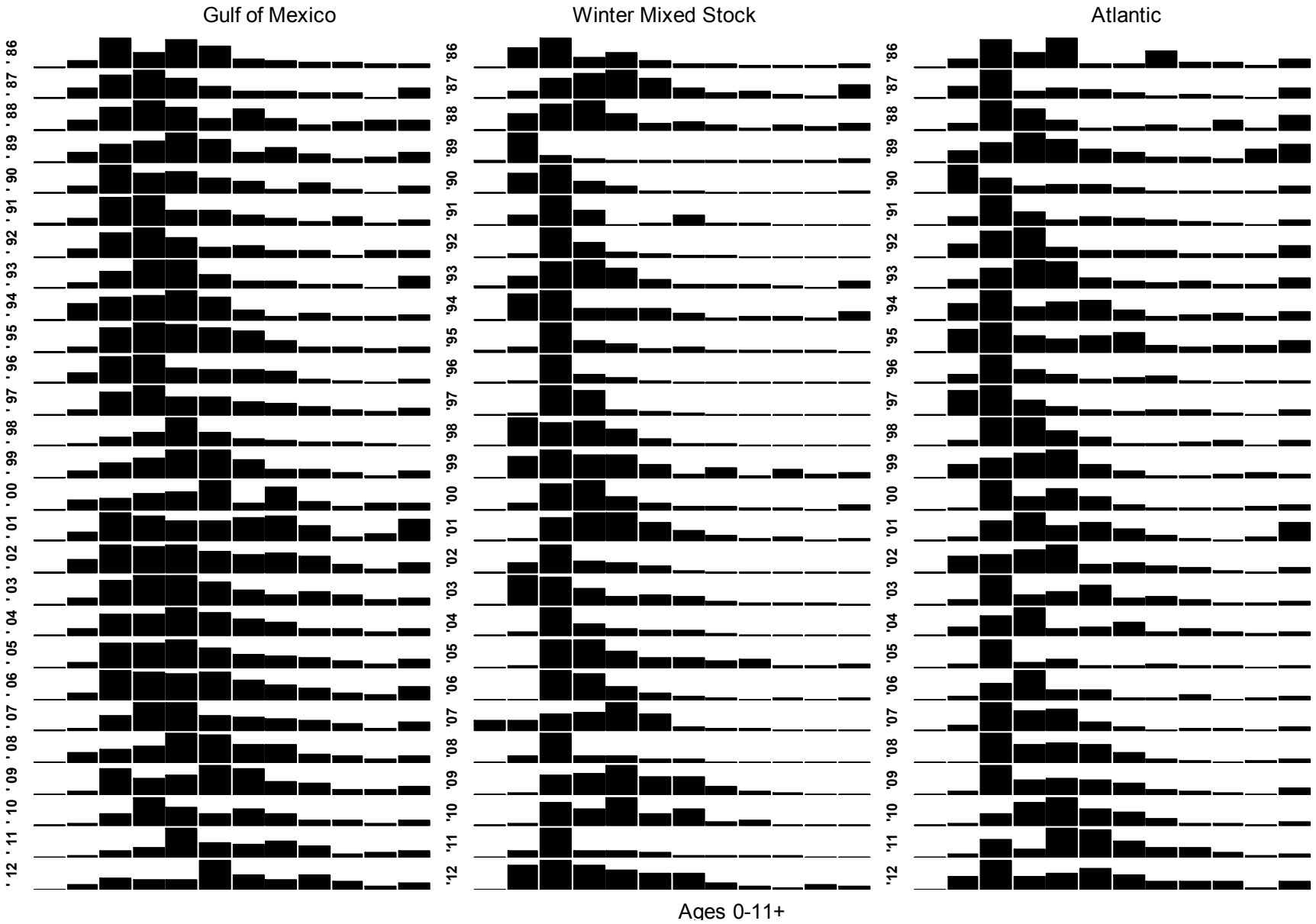


Figure 9. Age frequency distribution of King Mackerel caught in the recreational private fleet, continuity model.

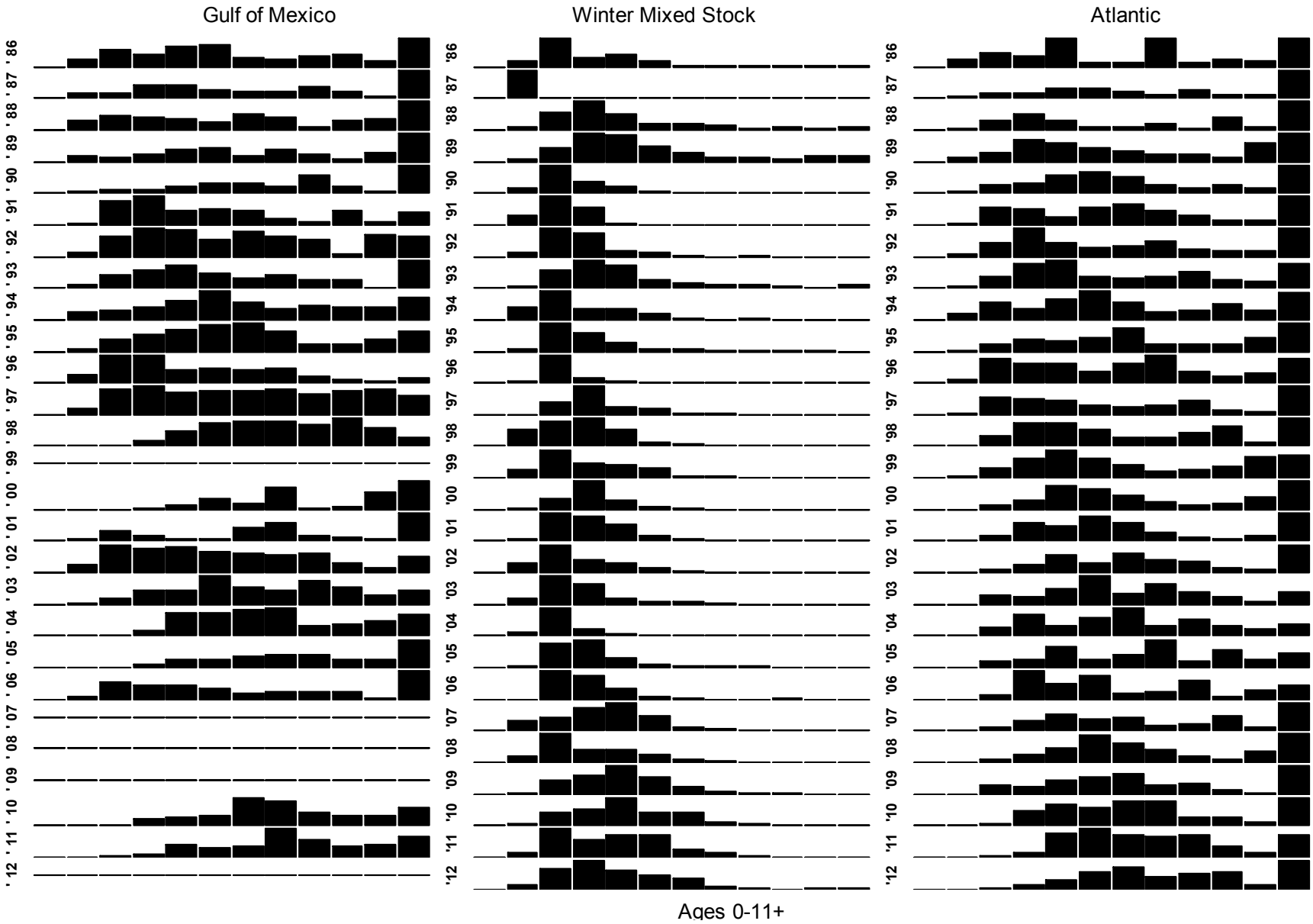


Figure 10. Age frequency distribution of King Mackerel caught in the recreational tournament fleet, continuity model.

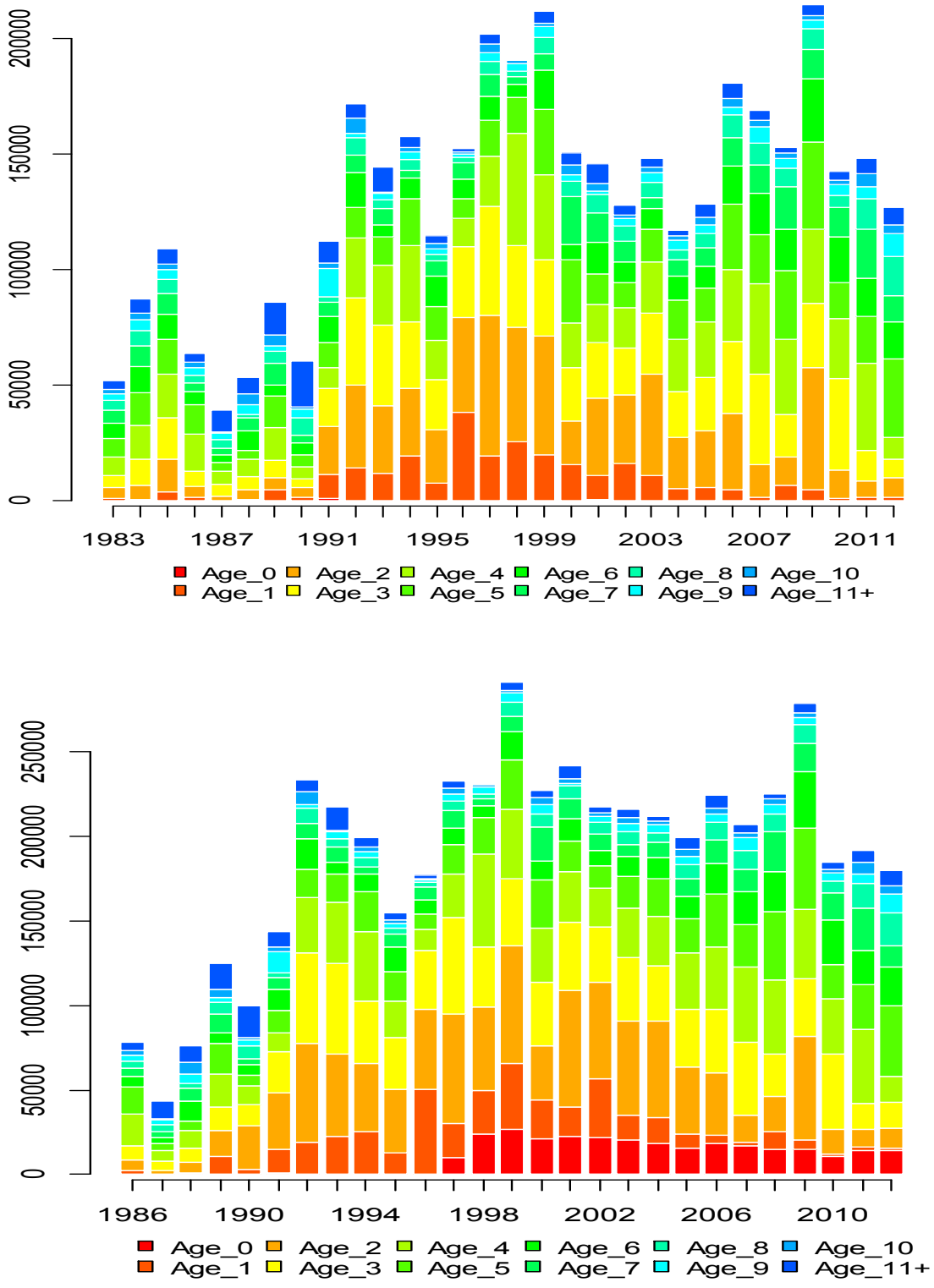


Figure 11. Partial catch-at-age of the commercial handline fleet in numbers of fish for the continuity VPA (upper figure) and base VPA (lower figure).

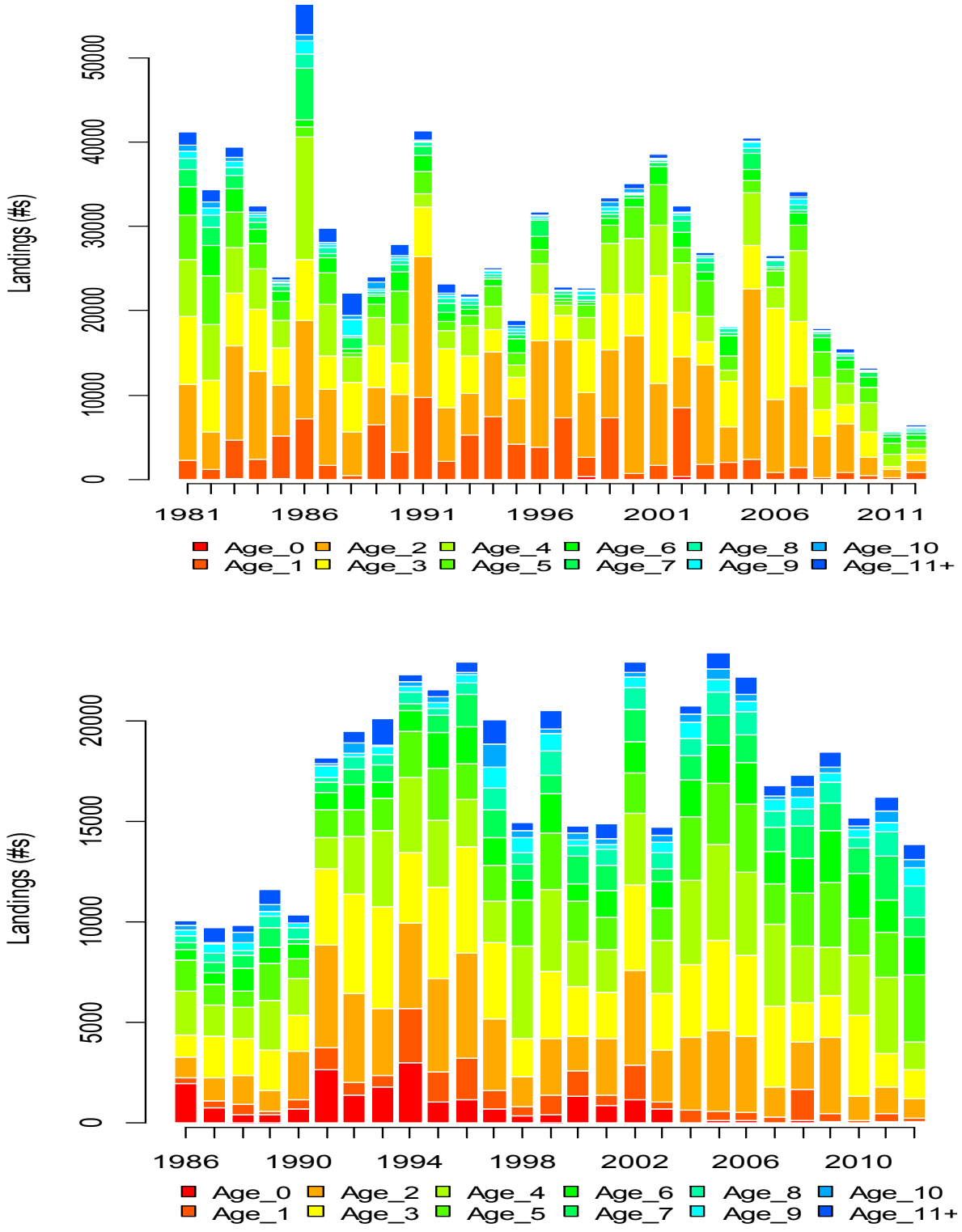


Figure 12. Partial catch-at-age of the recreational headboat fleet for the continuity VPA (upper figure) and base VPA (lower figure).

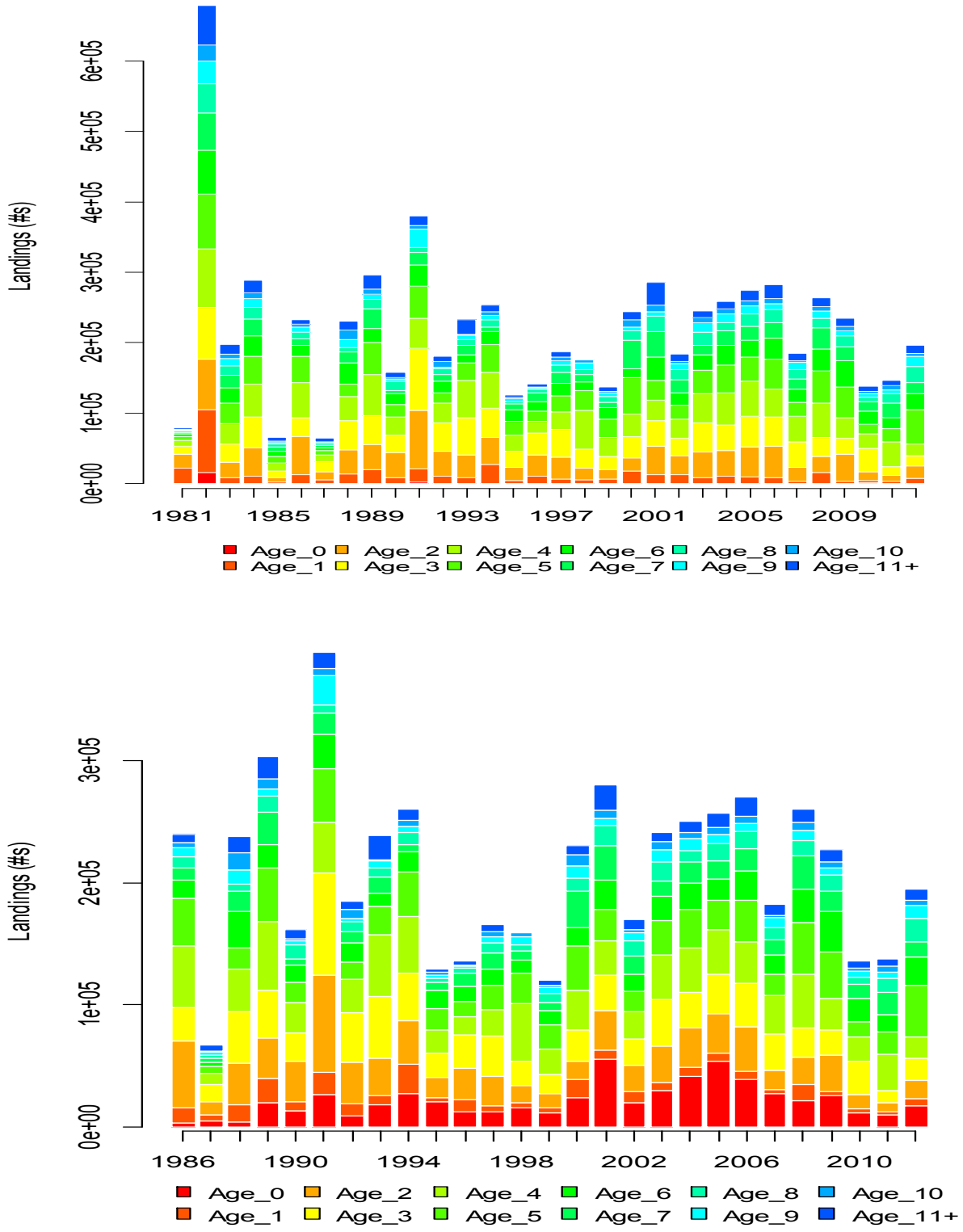


Figure 13. Partial catch-at-age of the recreational private and shore fleet for the continuity VPA (upper figure) and base VPA (lower figure).

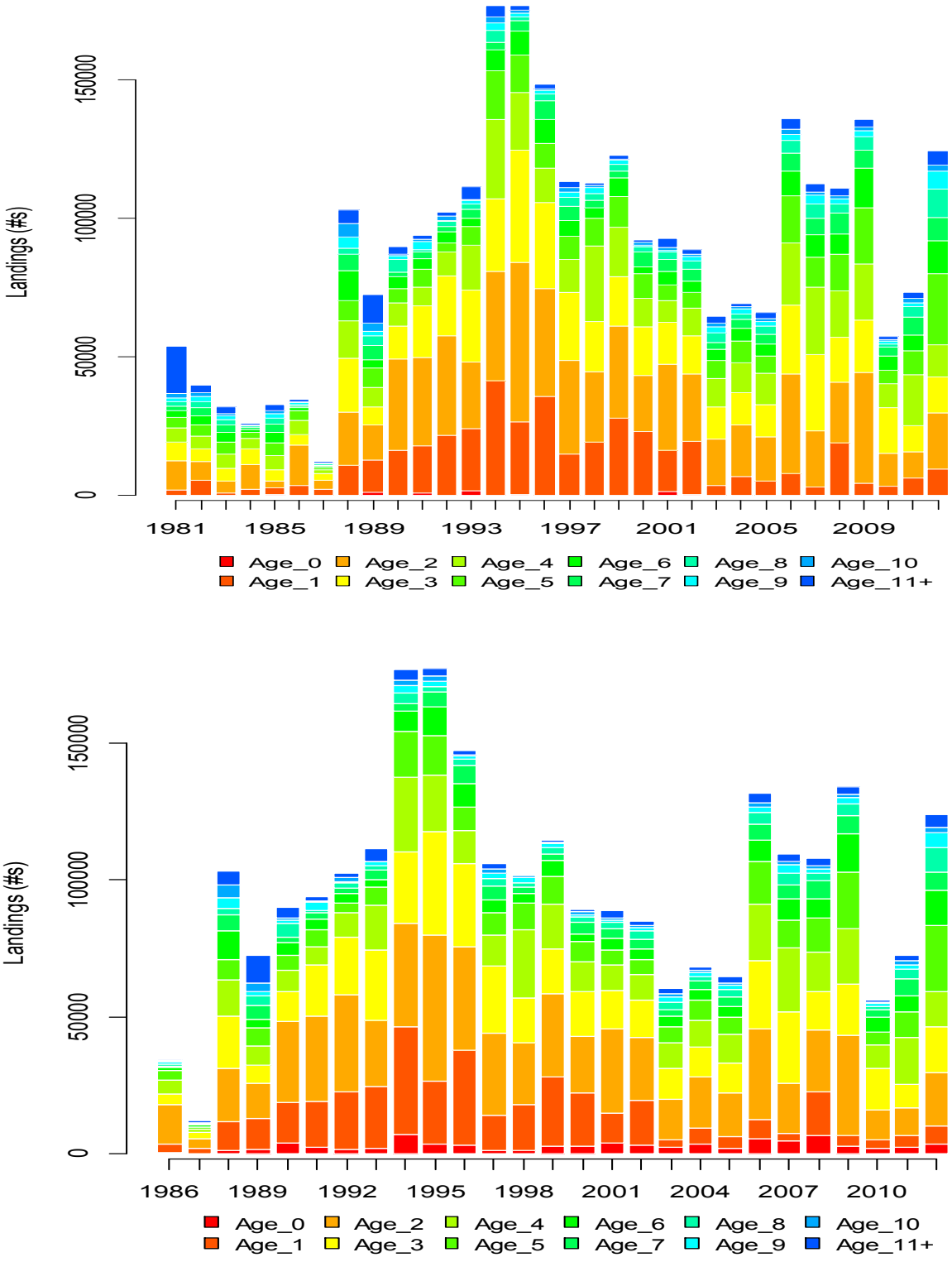


Figure 14. Partial catch-at-age of the recreational charter fleet for the continuity VPA (upper figure) and base VPA (lower figure).

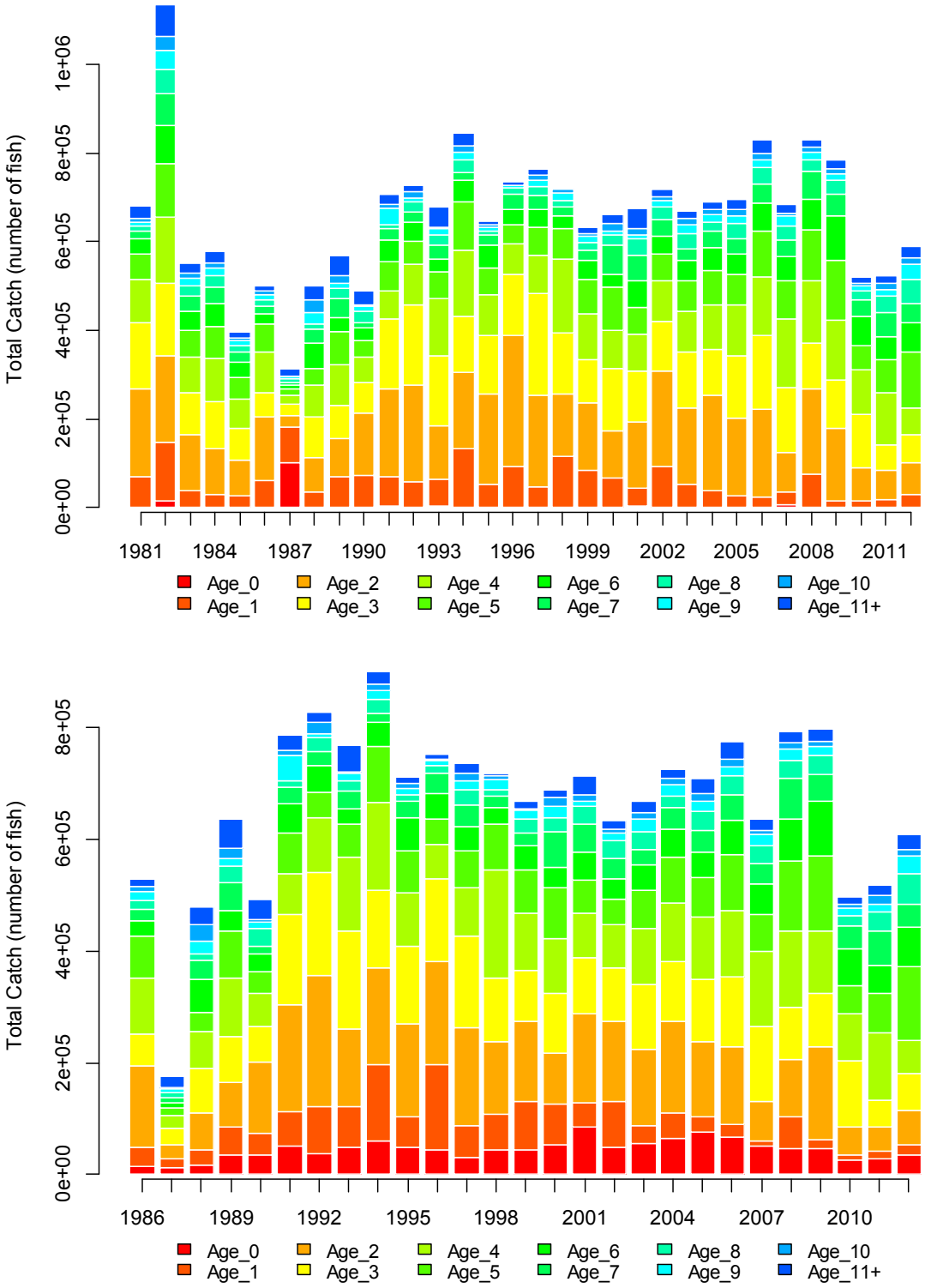
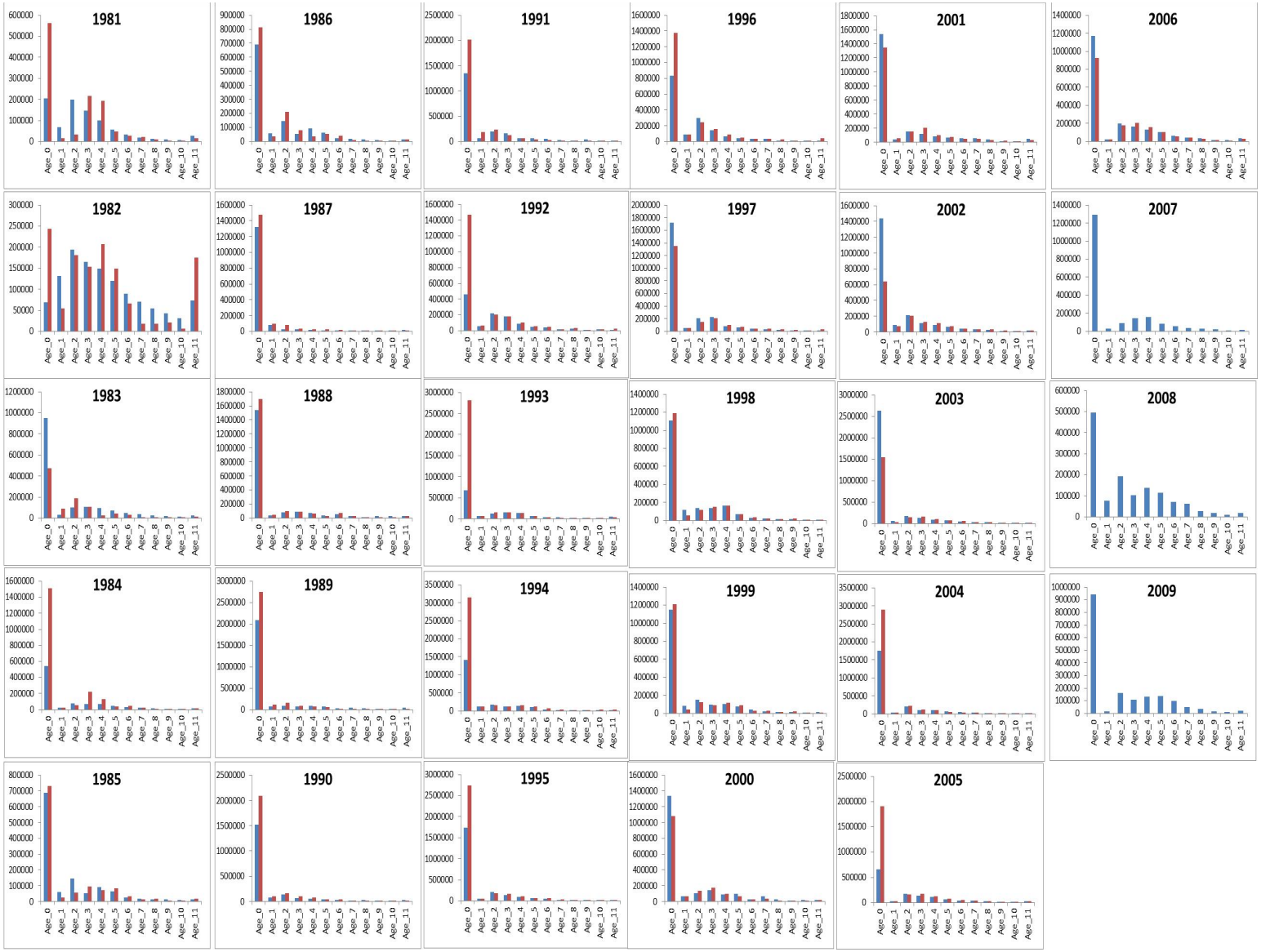


Figure 15. Total catch-at-age of Gulf of Mexico King Mackerel for the continuity VPA (upper figure) and base VPA (lower figure), excluding shrimp bycatch.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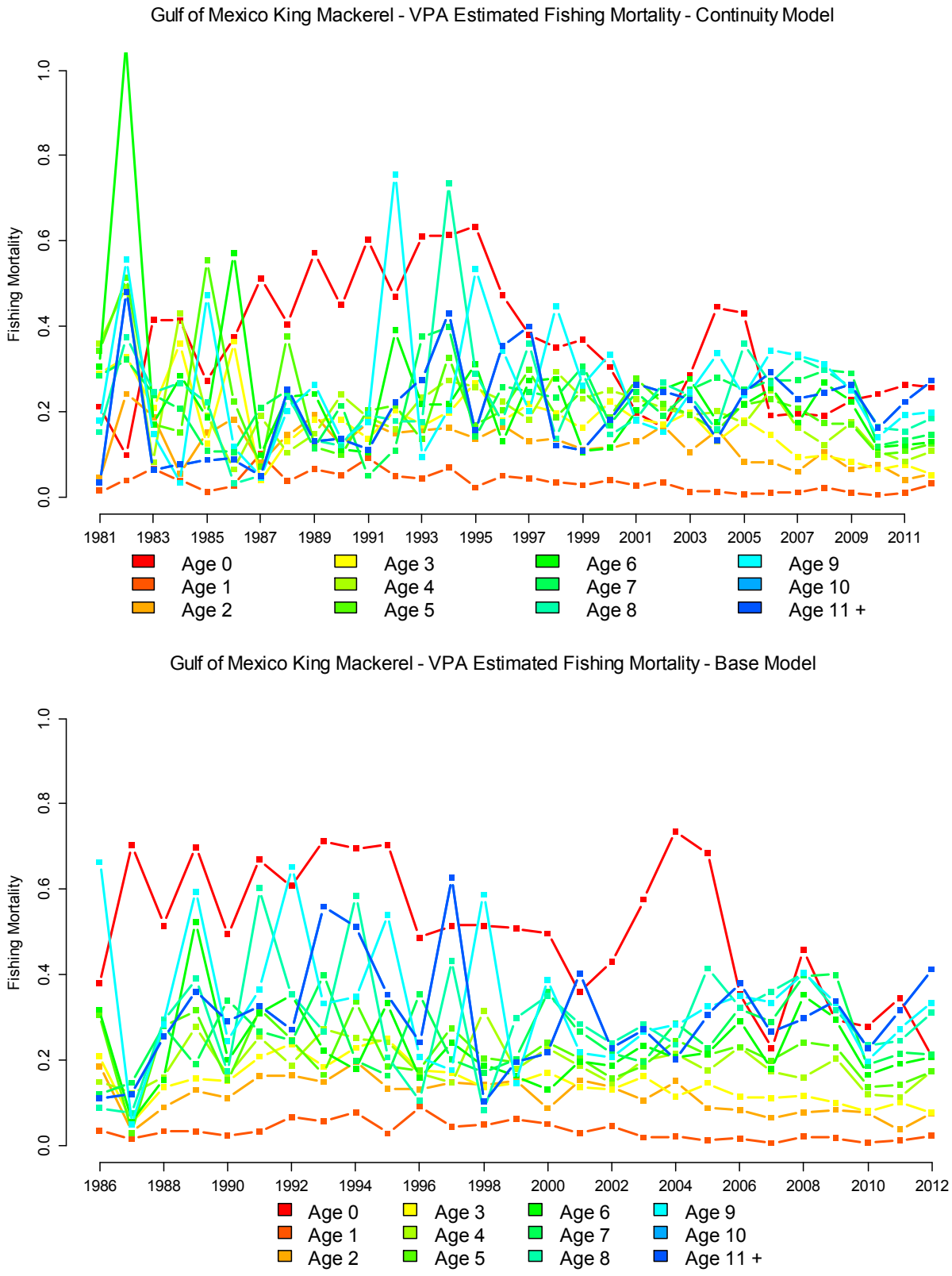


Figure 17. Estimated fishing mortality-at-age of Gulf of Mexico King Mackerel from the continuity VPA (upper figure) and base VPA (lower figure).

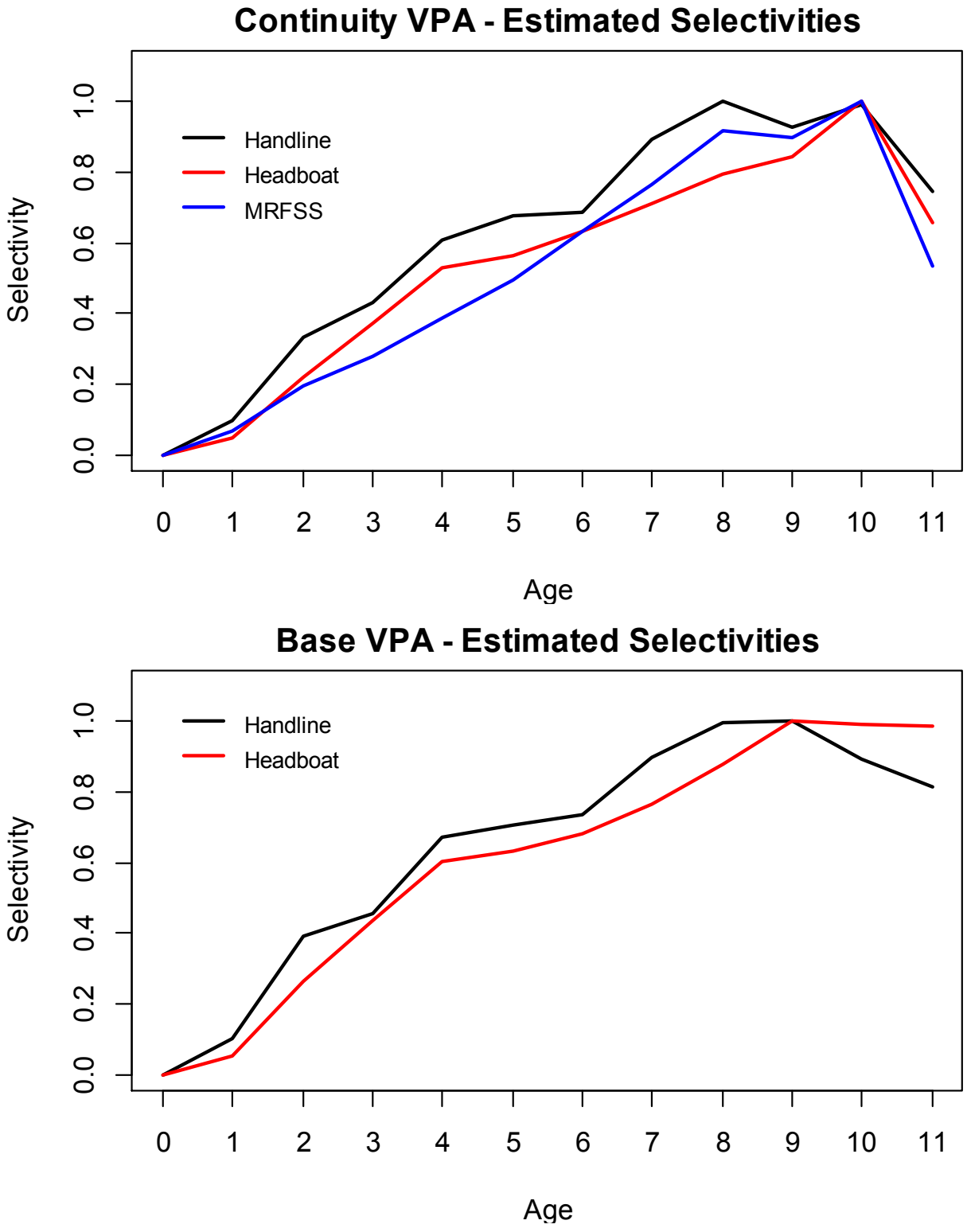


Figure 18. VPA estimated selectivity-at-age of commercial handline and recreational charter and private (MRFSS) and headboat fleets from the continuity (upper figure) and base models (lower figure).

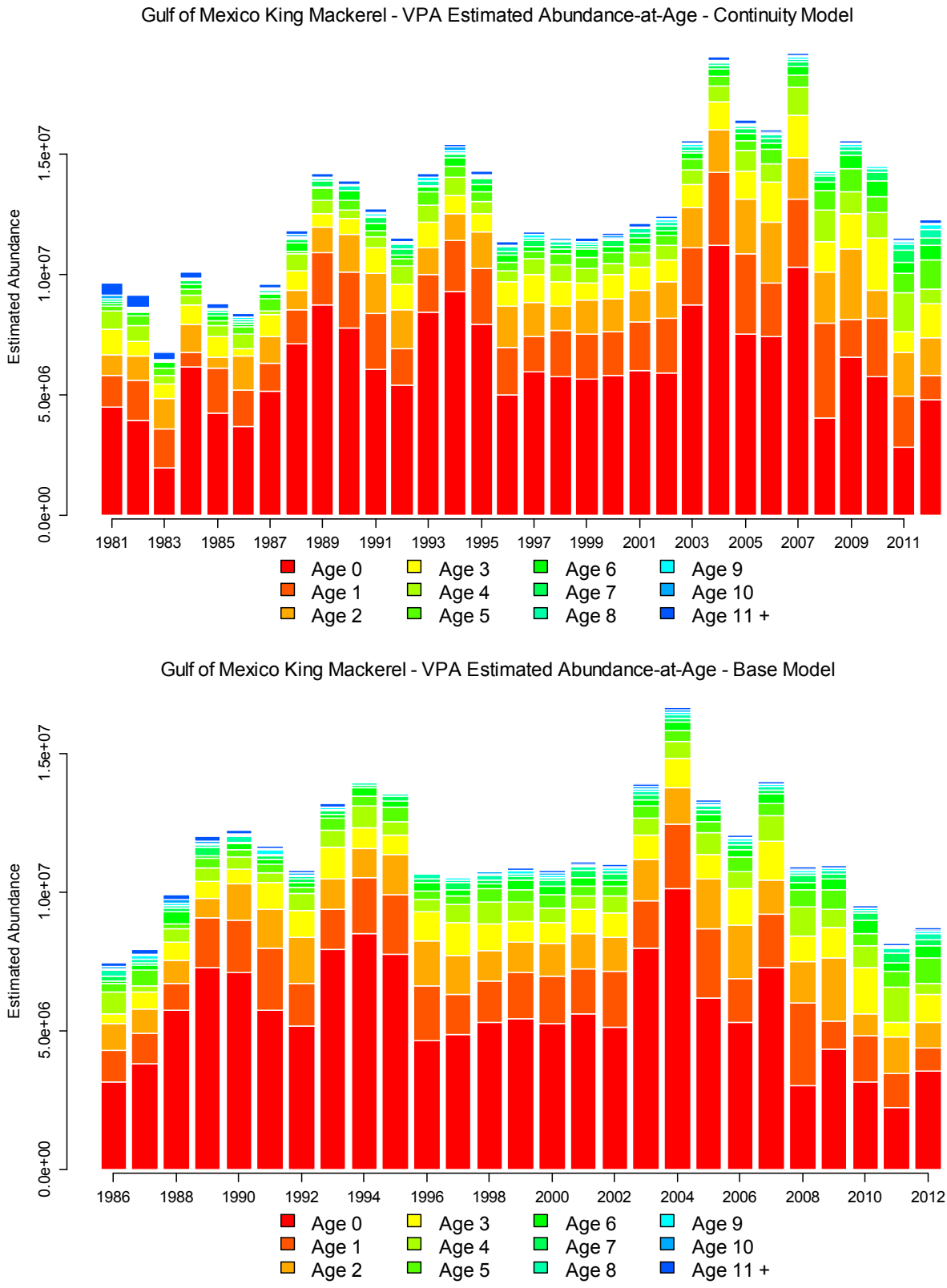


Figure 19. Estimated abundance-at-age of Gulf of Mexico King Mackerel from the continuity VPA (upper figure) and base VPA (lower figure).

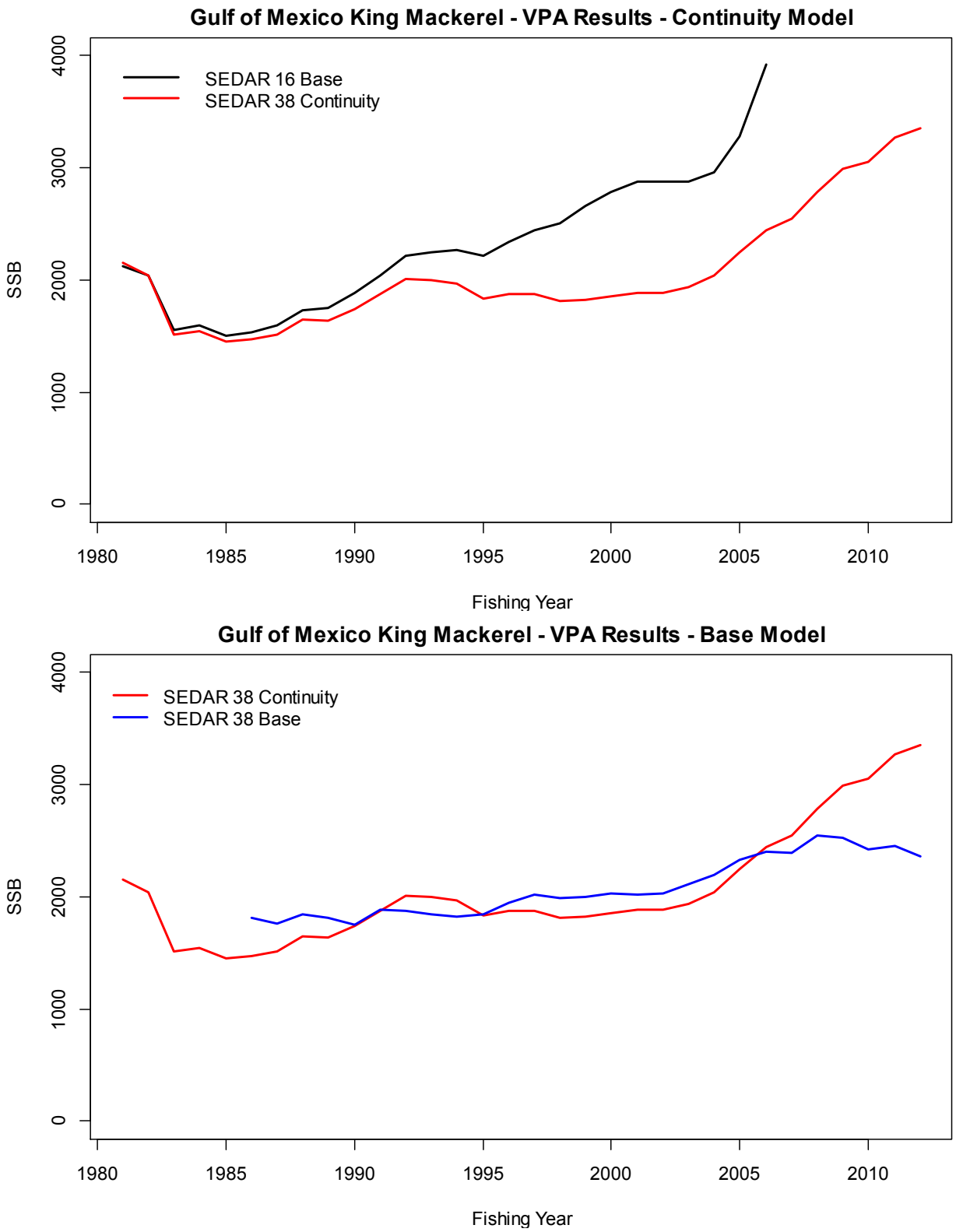
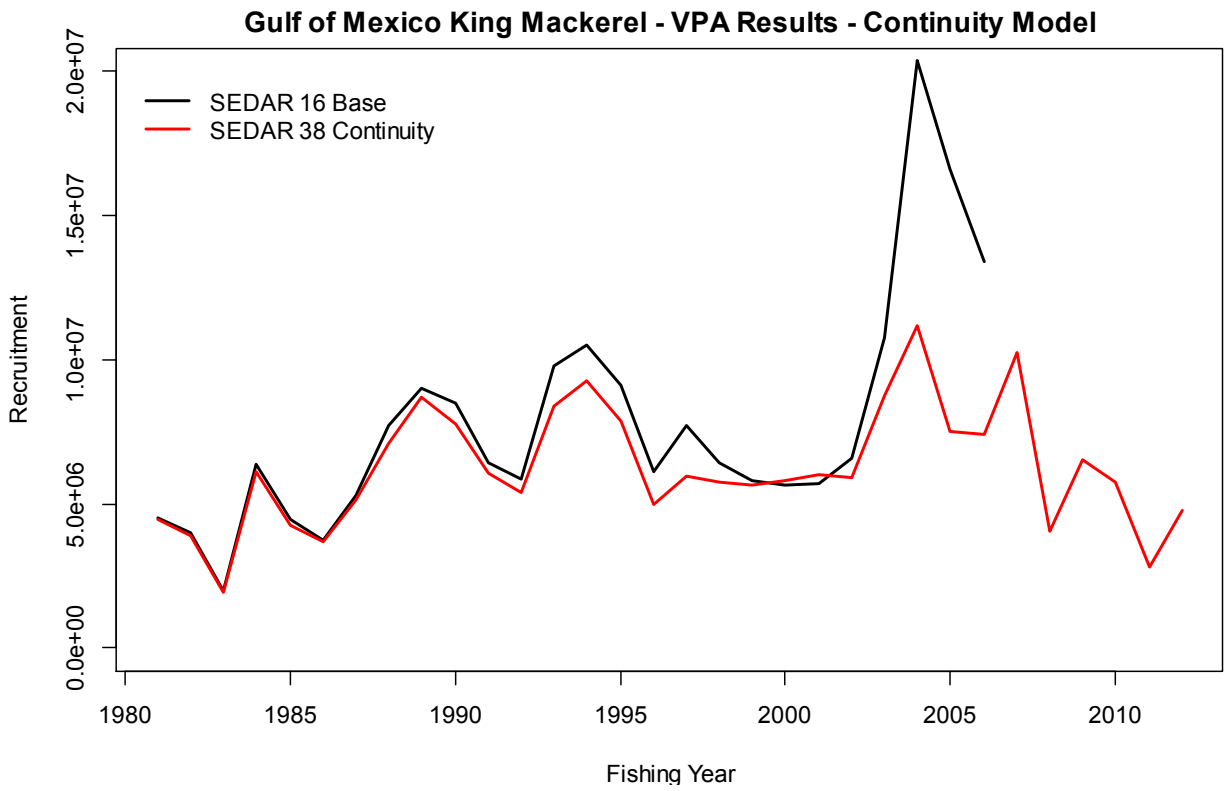


Figure 20. Estimated spawning stock biomass of Gulf of Mexico King Mackerel from the continuity VPA and base VPA.



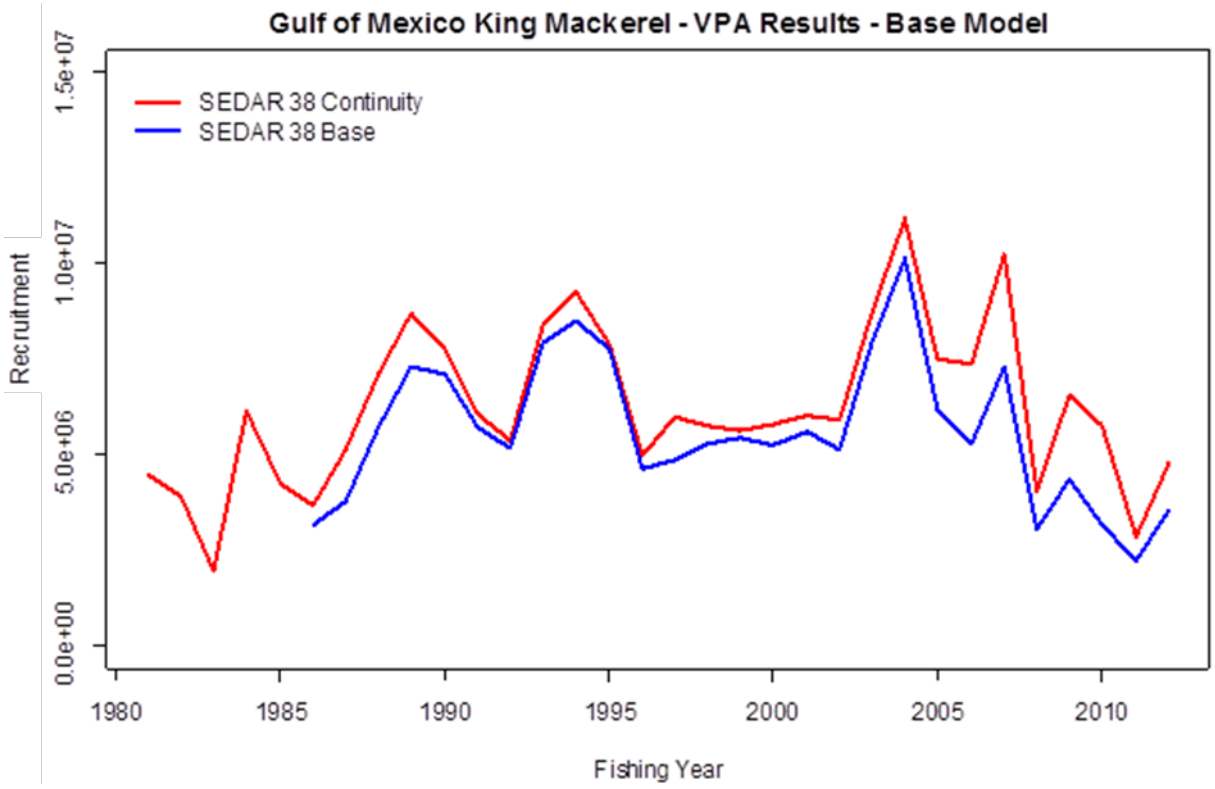


Figure 21. Estimated recruitment of Gulf of Mexico King Mackerel from the continuity VPA (upper figure) and base VPA (lower figure).

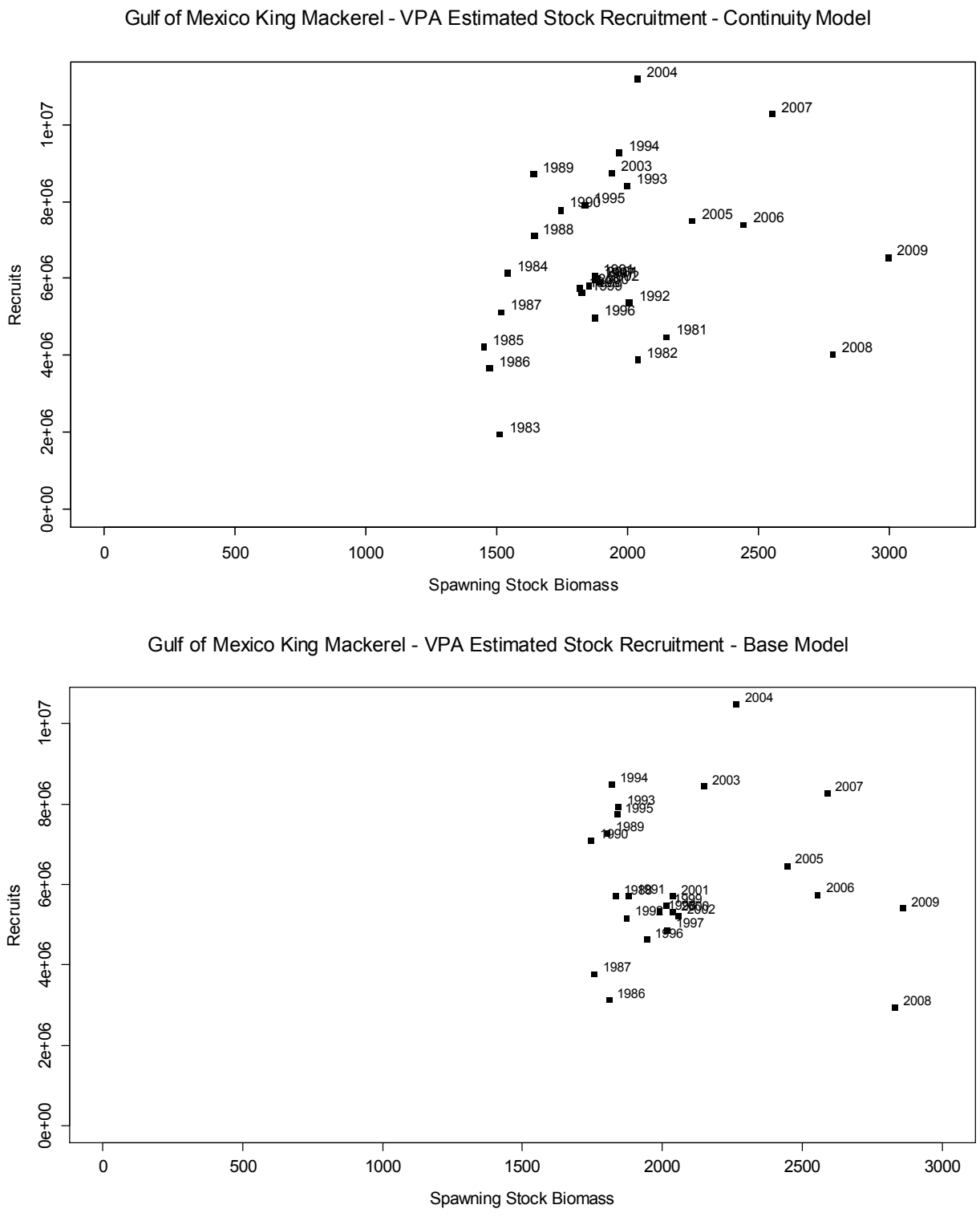


Figure 22. Relationship between estimated recruitment and spawning stock biomass of Gulf of Mexico King Mackerel, estimated by the continuity VPA (upper figure) and base VPA (lower figure).

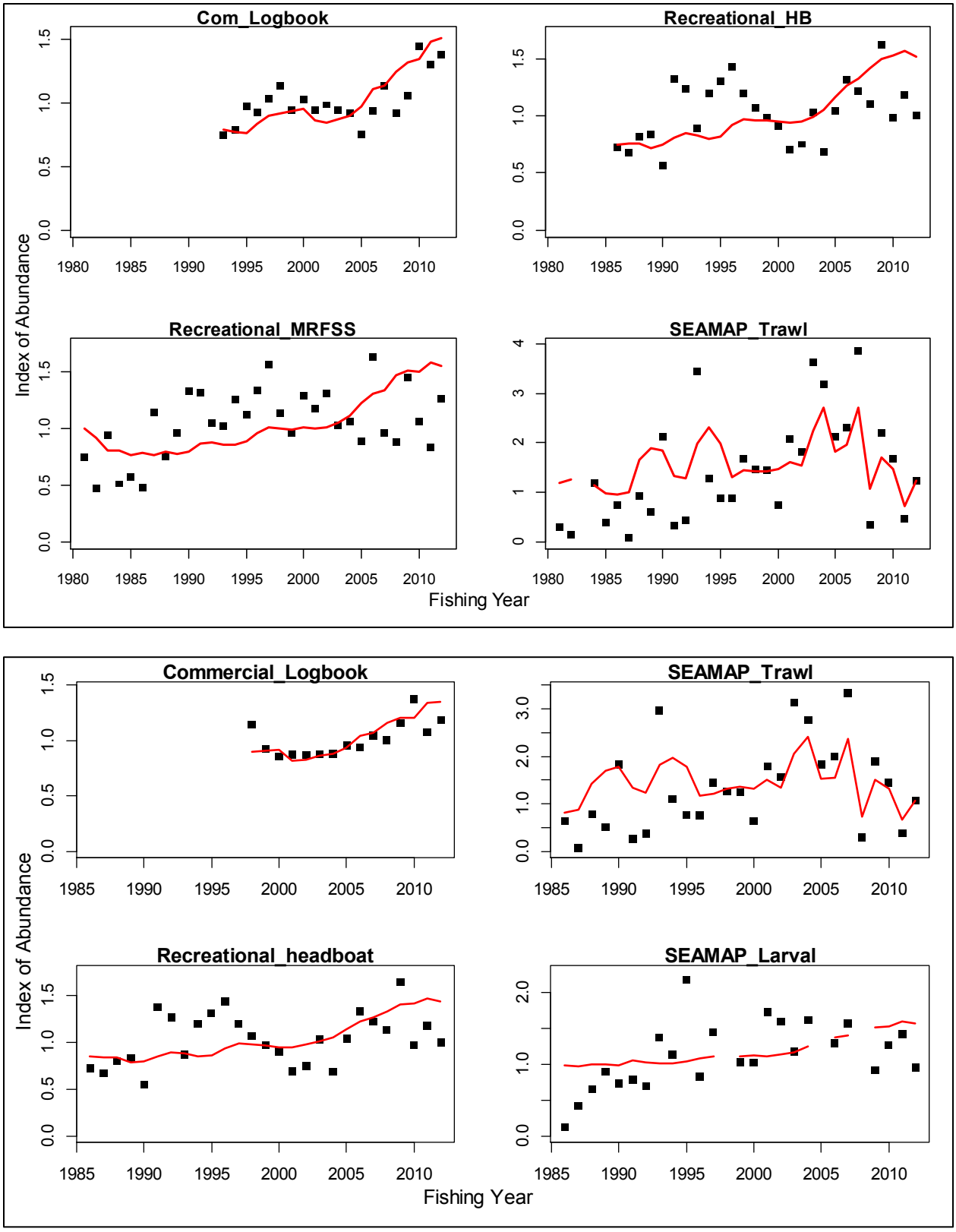


Figure 23. Model fits to indices of abundance of Gulf of Mexico King Mackerel for the continuity VPA (upper set of figures) and base VPA (lower set of figure).

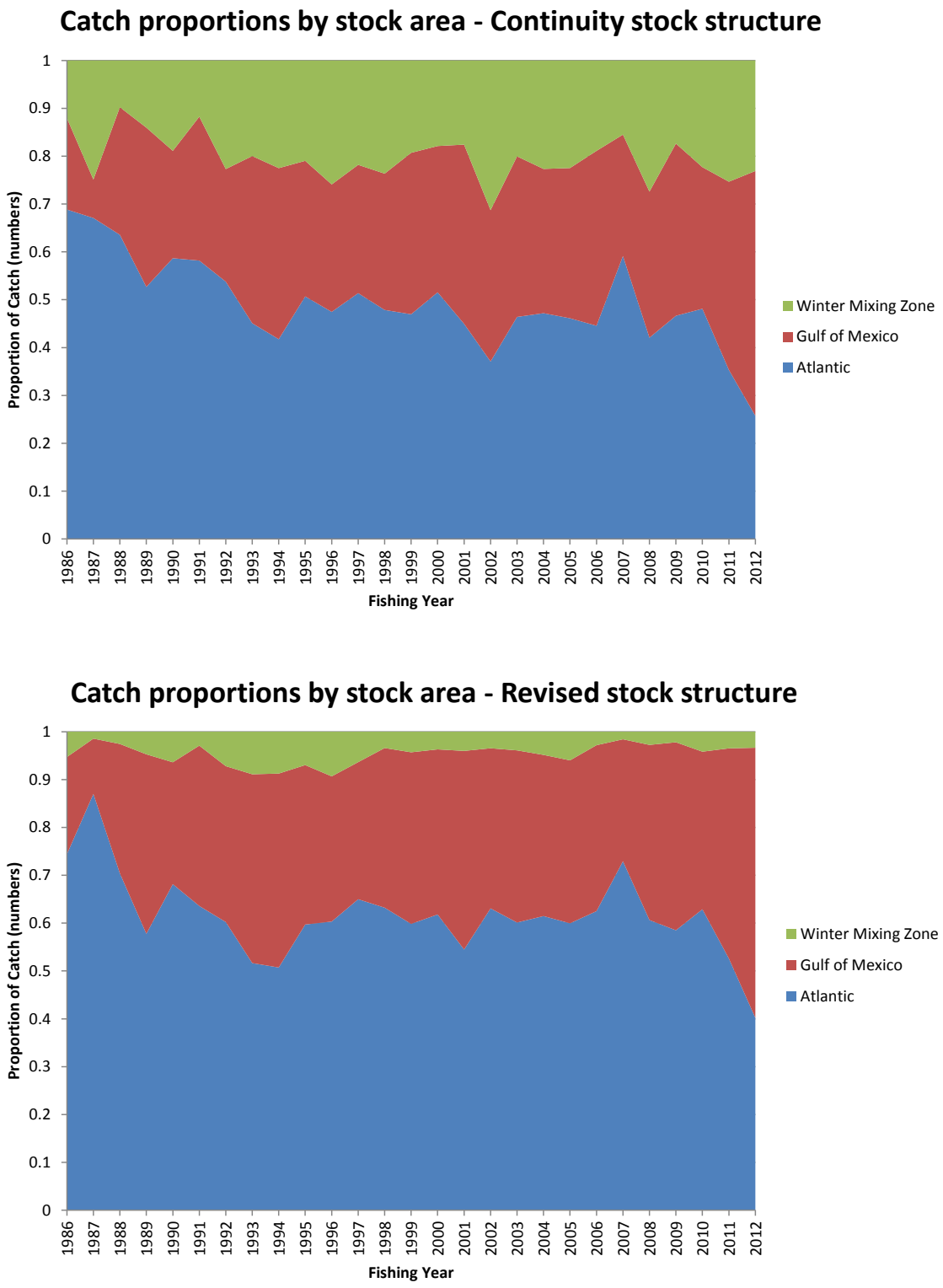


Figure 24. Estimated catch proportions by stock under the continuity (upper figure) and revised (lower figure) stock structure assumptions.

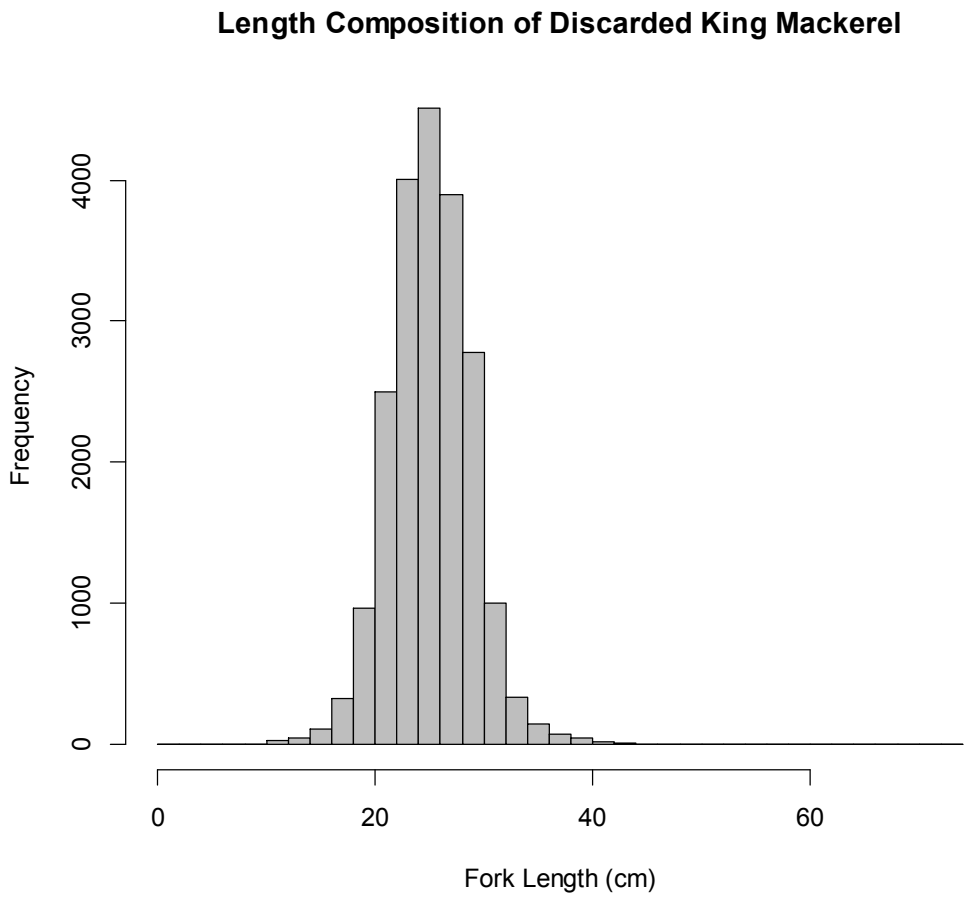


Figure 25. Size frequency distribution of King Mackerel discarded on observer reported recreational trips in Florida. Data provided by the Florida Fish and Wildlife Conservation Commission (unpublished) at the SEDAR 38 Assessment Workshop.

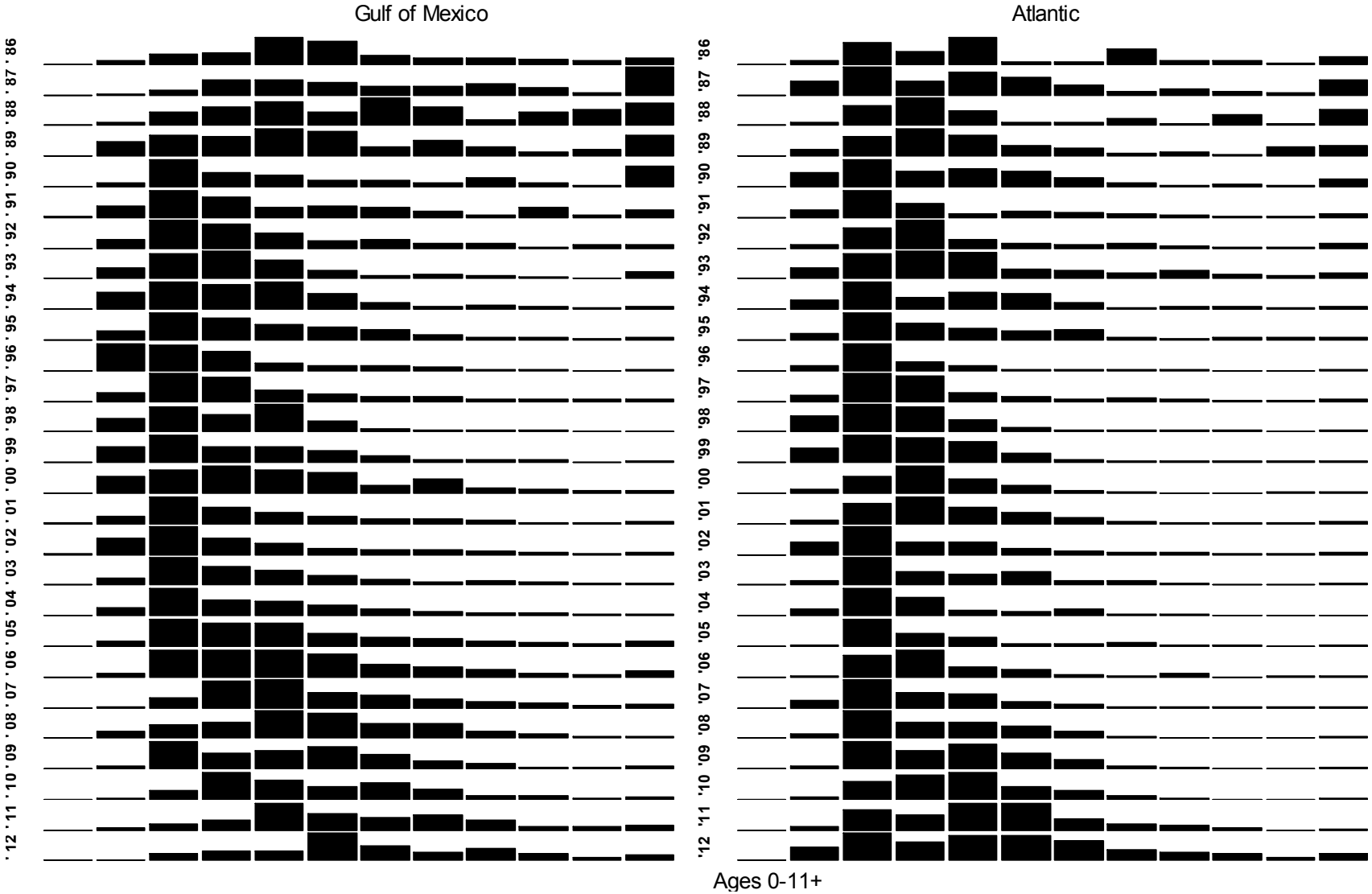


Figure 26. Age-frequency distributions of Gulf of Mexico and Atlantic King Mackerel in the commercial handline fishery under the revised stock structure assumptions. Note that the sample sizes in the redefined mixing zone were minimal and distributions are not shown.

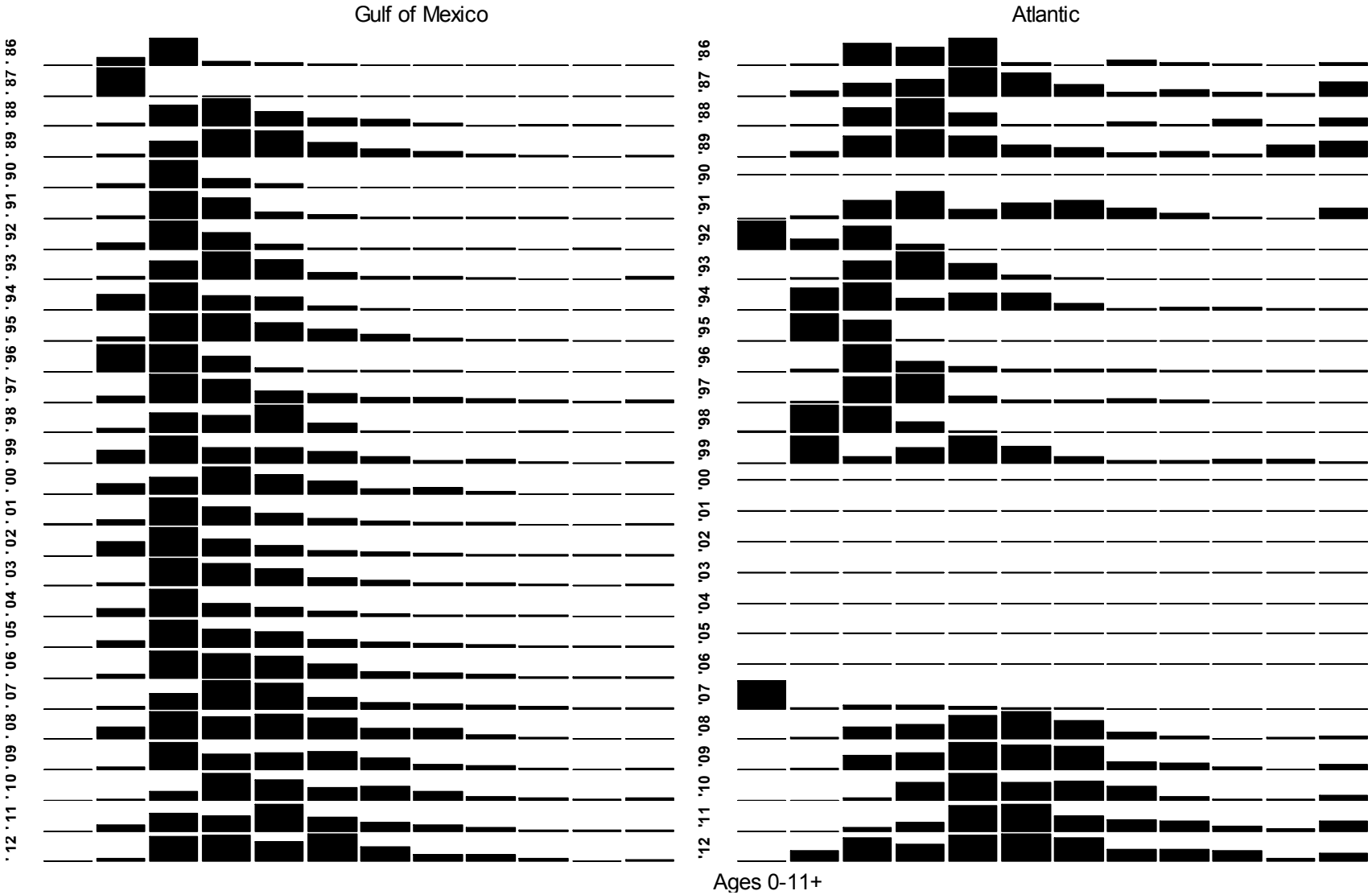


Figure 27. Age-frequency distributions of Gulf of Mexico and Atlantic King Mackerel in the commercial gillnet fishery under the revised stock structure assumptions. Note that the sample sizes in the redefined mixing zone were minimal and distributions are not shown.

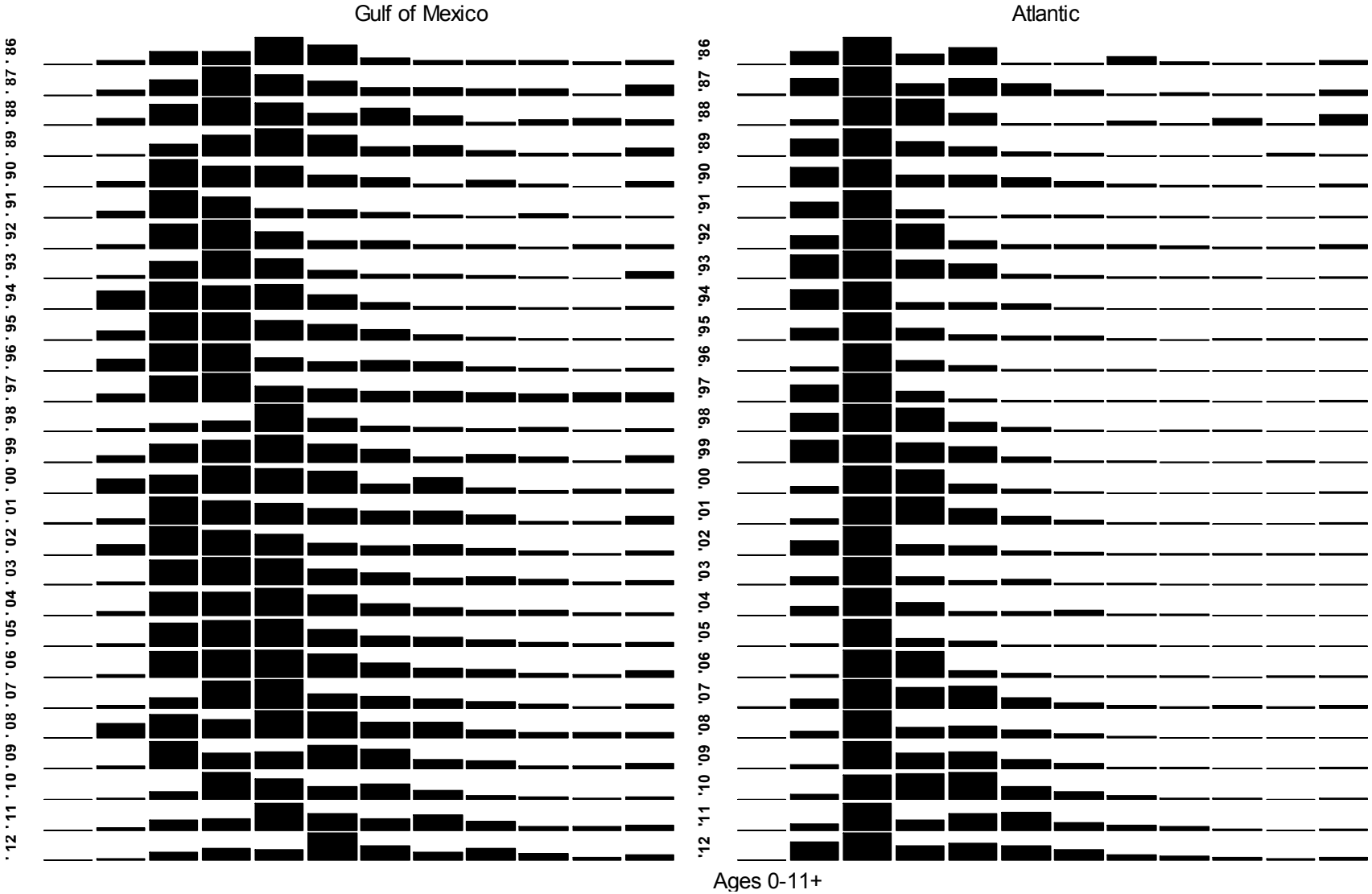


Figure 28. Age-frequency distributions of Gulf of Mexico and Atlantic King Mackerel in the recreational headboat fishery under the revised stock structure assumptions. Note that the sample sizes in the redefined mixing zone were minimal and distributions are not shown.

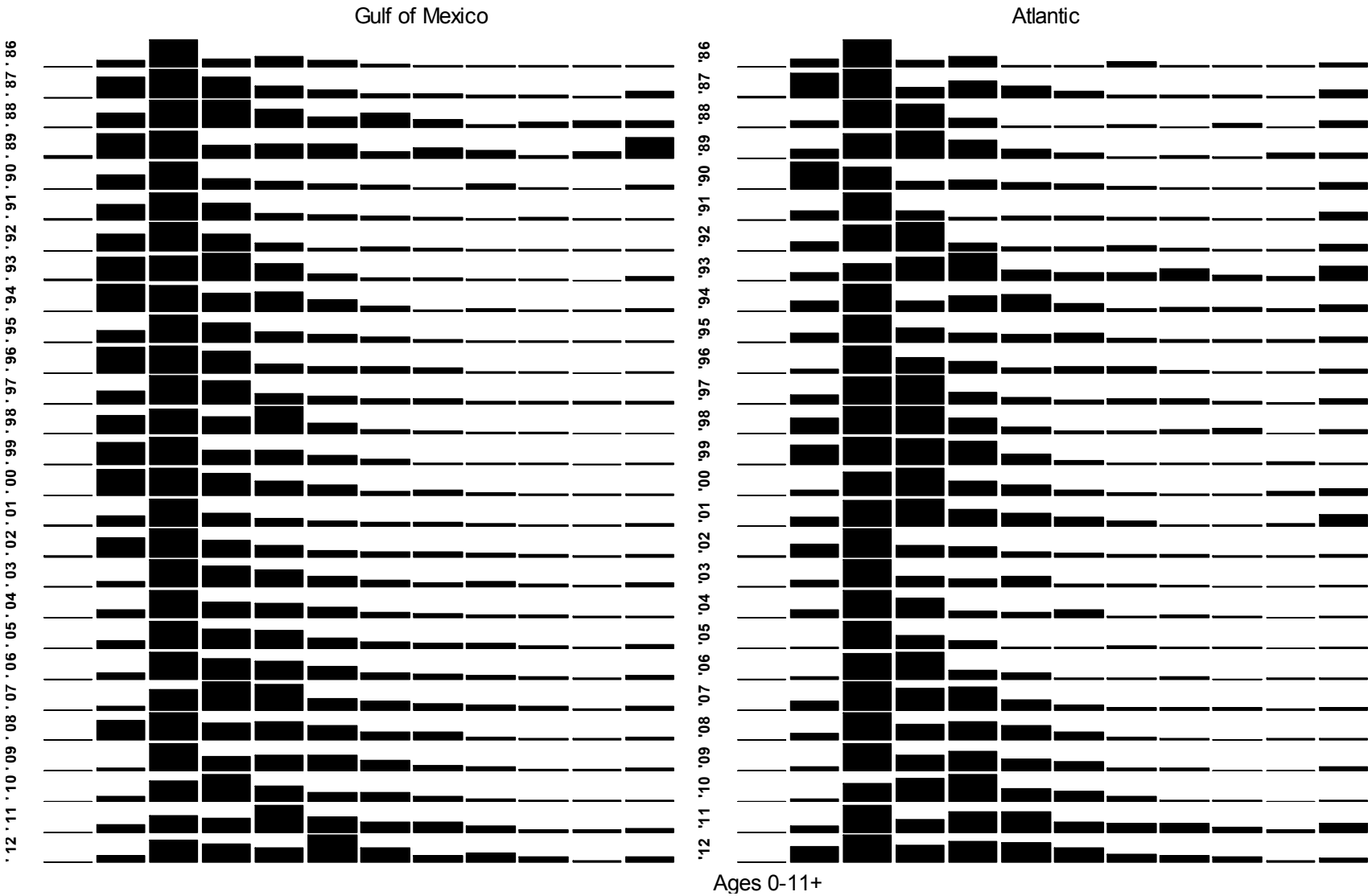


Figure 29. Age-frequency distributions of Gulf of Mexico and Atlantic King Mackerel in the recreational charter boat fishery under the revised stock structure assumptions. Note that the sample sizes in the redefined mixing zone were minimal and distributions are not shown.

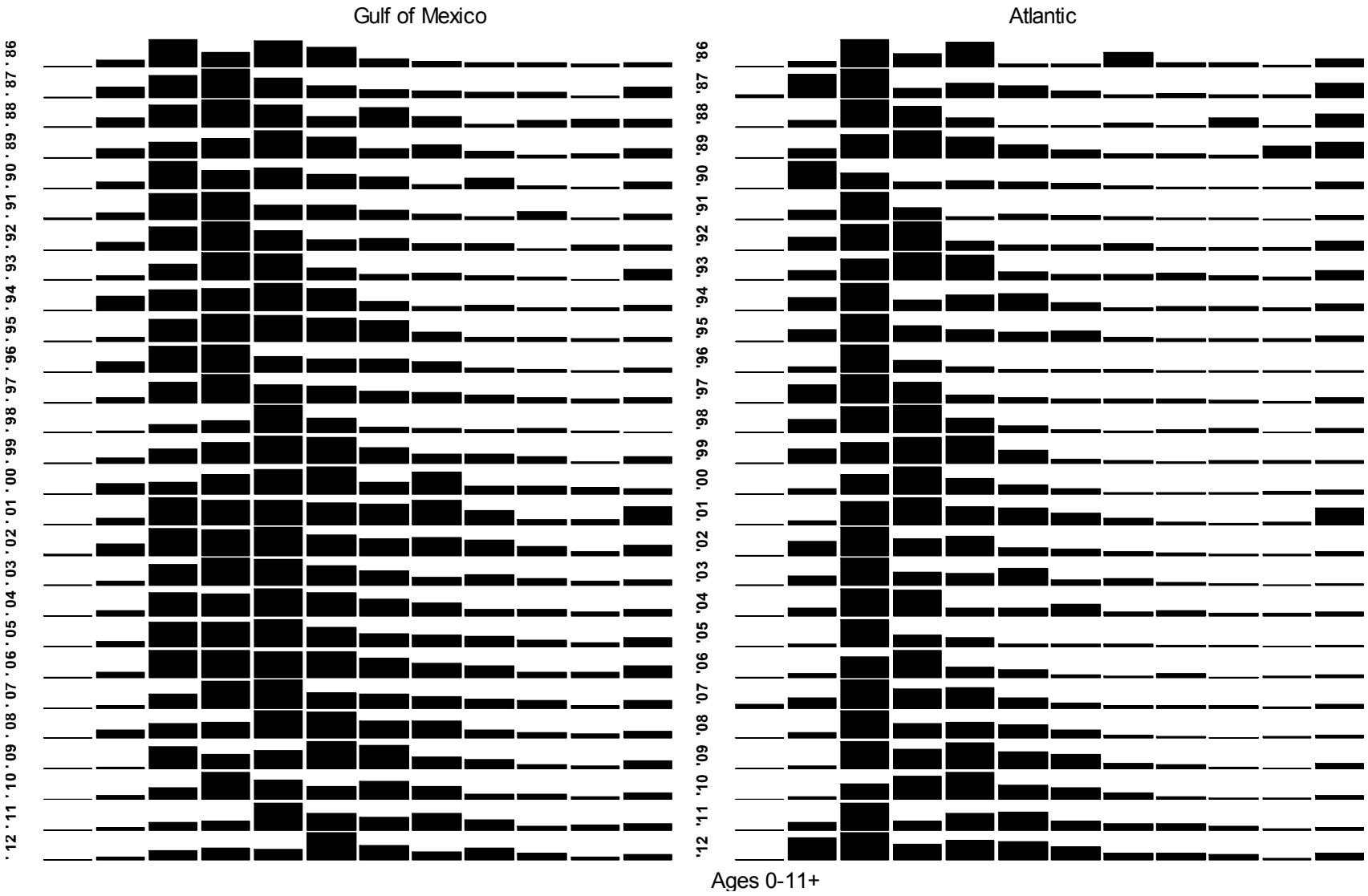


Figure 30. Age-frequency distributions of Gulf of Mexico and Atlantic King Mackerel in the recreational private boat fishery under the revised stock structure assumptions. Note that the sample sizes in the redefined mixing zone were minimal and distributions are not shown.

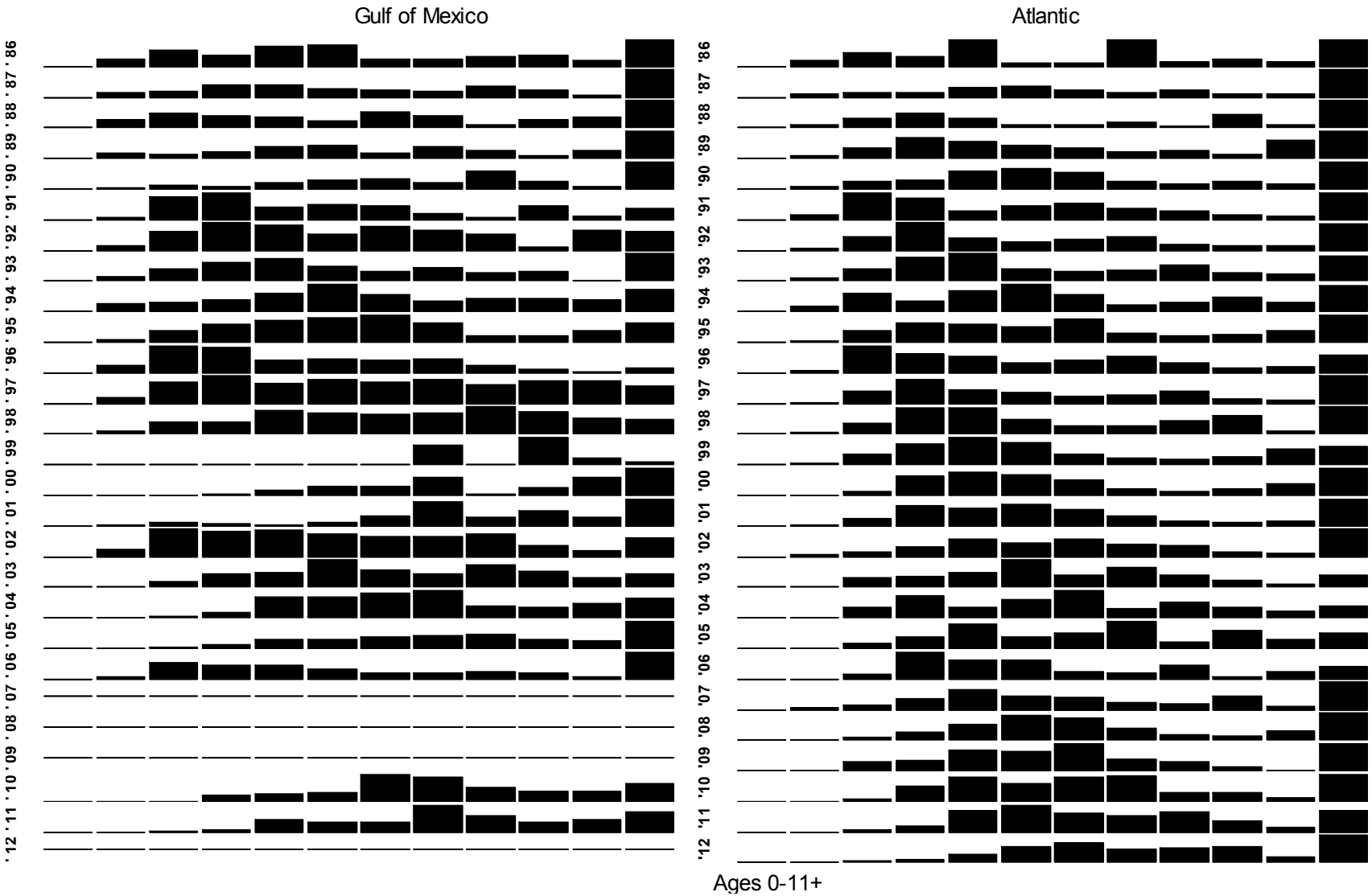


Figure 31. Age-frequency distributions of Gulf of Mexico and Atlantic King Mackerel in the recreational tournament fishery under the revised stock structure assumptions. Note that the sample sizes in the redefined mixing zone were minimal and distributions are not shown.

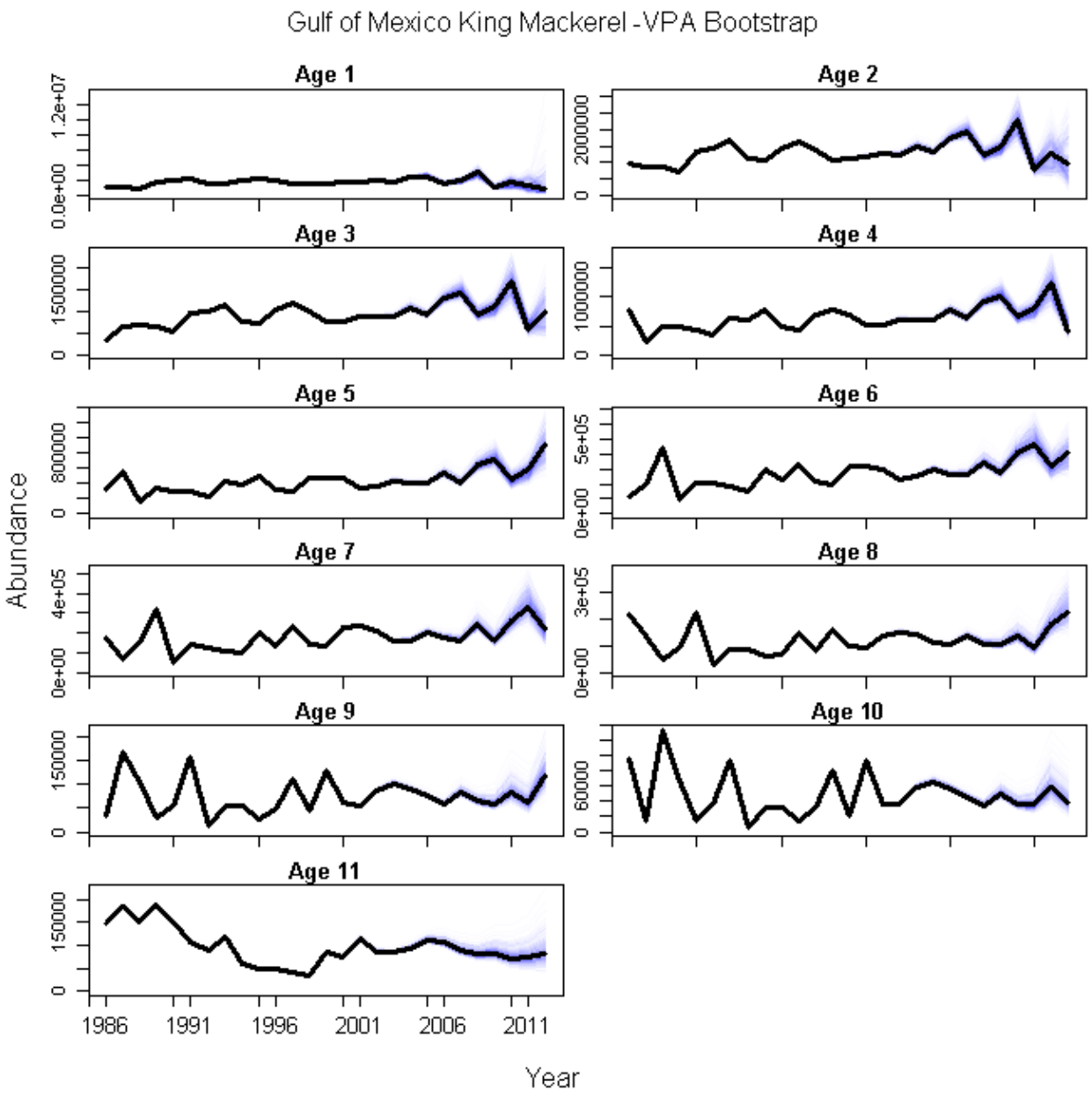


Figure 32. Parametric bootstrap analysis of the Base VPA for Gulf of Mexico King Mackerel. The estimates of abundance-at-age are shown for 500 bootstrap iterations, and the density of estimates is represented in blue shading.

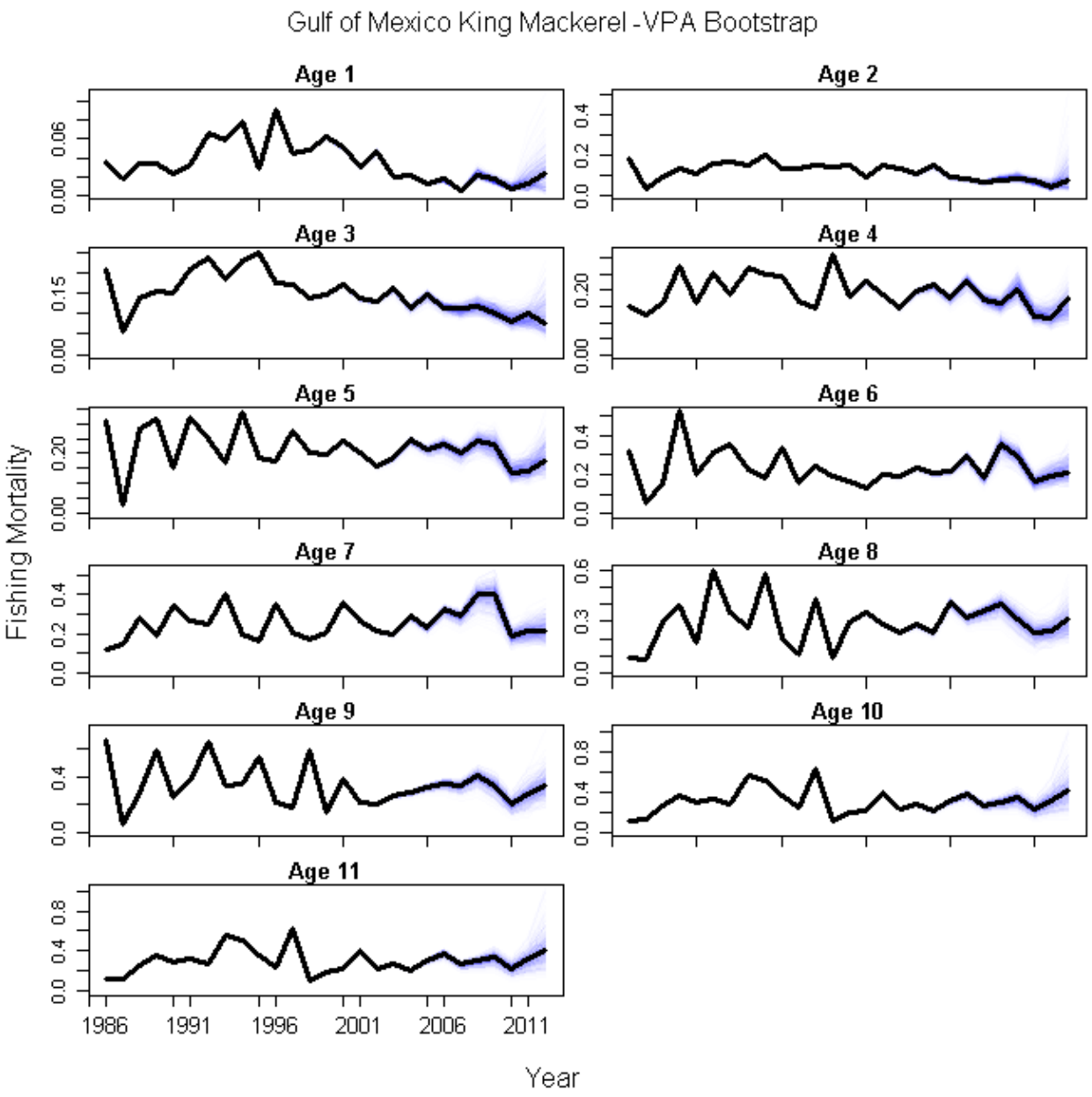


Figure 33. Parametric bootstrap analysis of the Base VPA for Gulf of Mexico King Mackerel. The estimates of fishing mortality-at-age are shown for 500 bootstrap iterations, and the density of estimates is represented in blue shading.

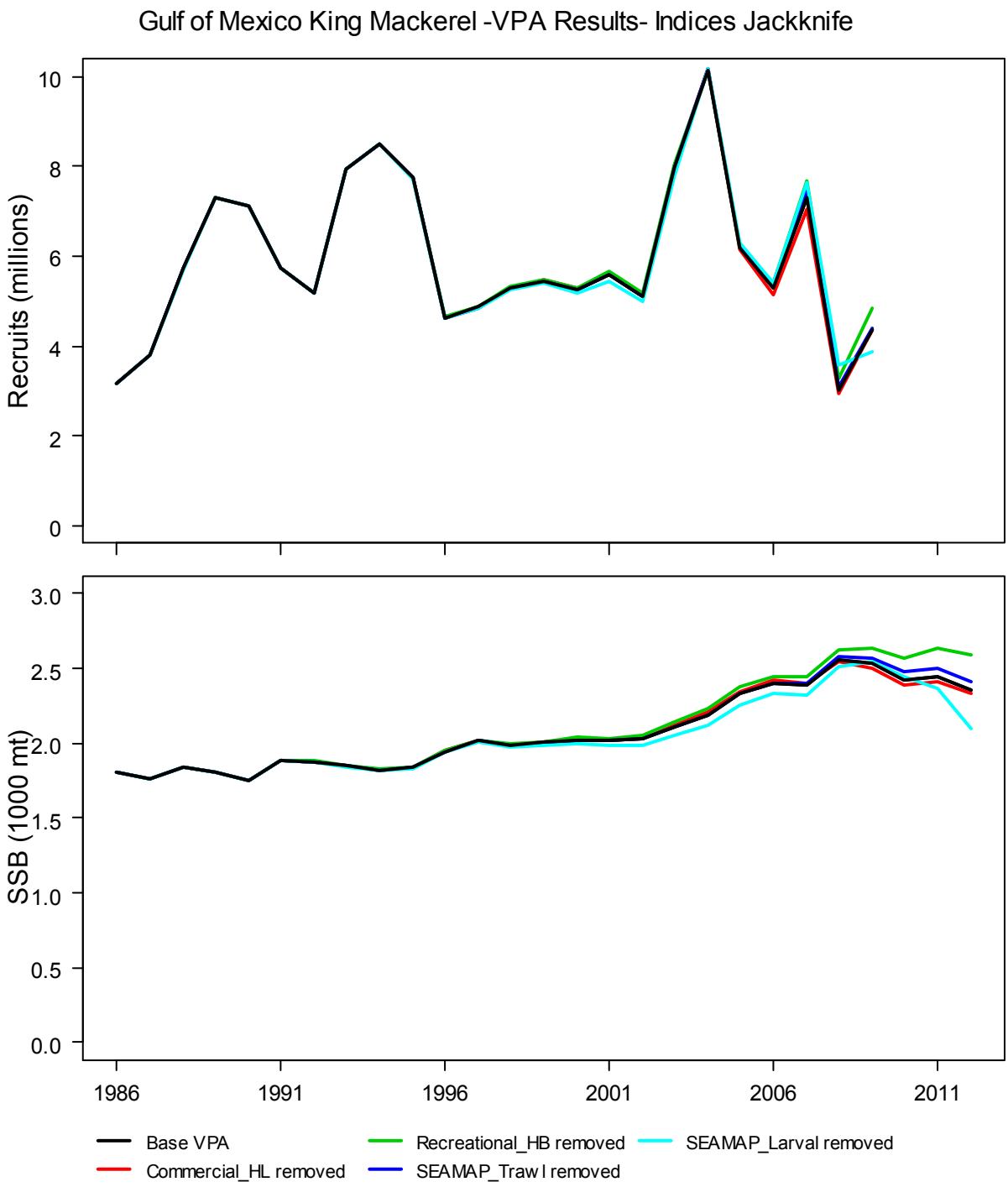


Figure 34. Indices jackknife sensitivity showing the effects of removing each index from the Base VPA on estimates of recruitment and spawning stock biomass (SSB).

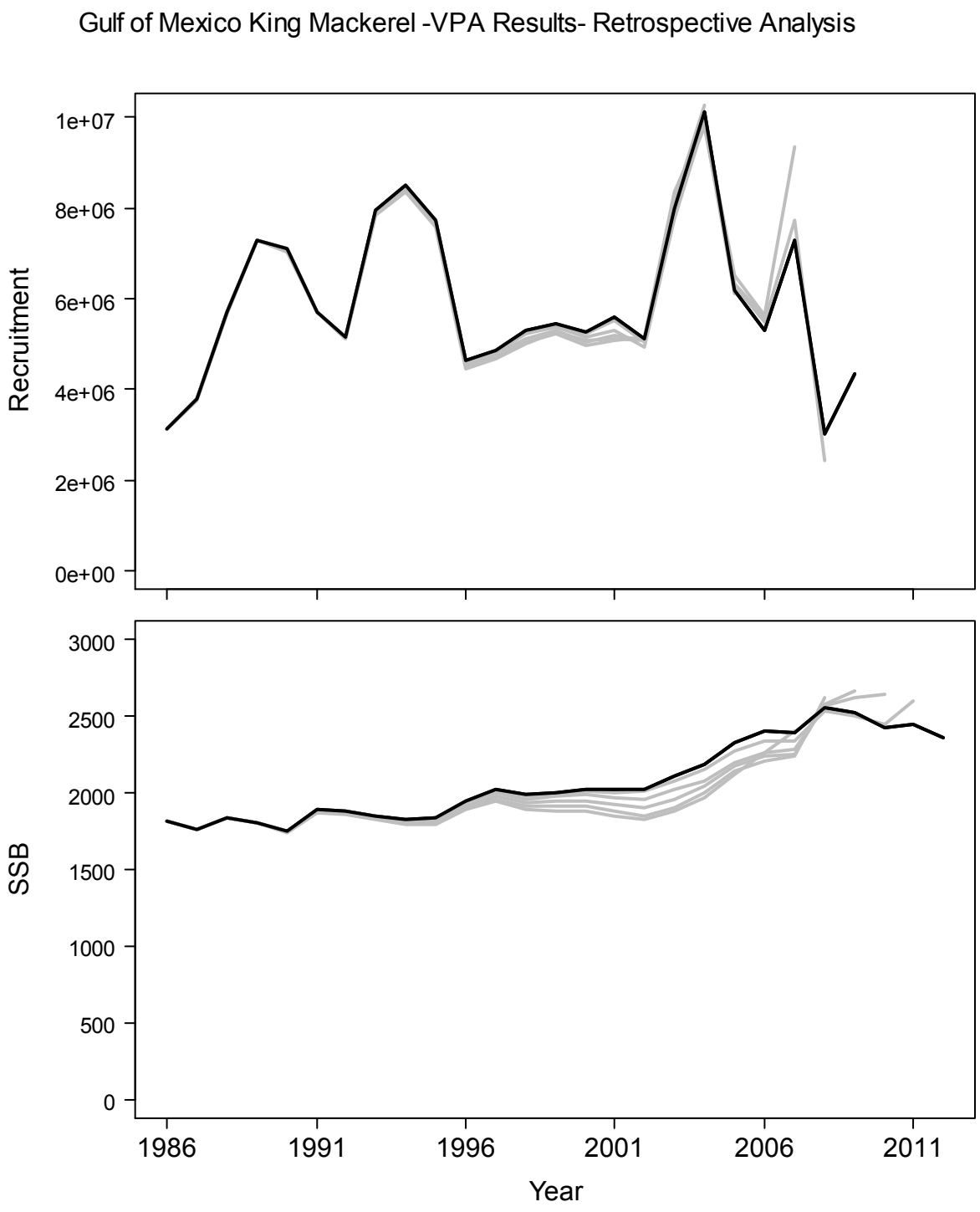


Figure 35. Retrospective analysis sensitivity demonstrating the effect of sequentially removing up to 10 years of data on estimates of recruitment and spawning stock biomass (SSB) from the Base VPA.