STANDARDIZED CATCH RATES OF KING MACKEREL (*Scomberomorus cavalla*) FROM U.S. GULF OF MEXICO AND SOUTH ATLANTIC RECREATIONAL FISHERIES

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April 2002

Sustainable Fisheries Division Contribution SFD-01/02-155

SUMMARY

Standardized indices of abundance were estimated for king mackerel in the US Gulf of Mexico and Southeastern US Atlantic from two recreational fisheries data sets; the Marine Recreational Fishery Statistics Survey (MRFSS) of private and charter recreational boats, and the Texas Parks and Wildlife Division Recreational Angler Creel Survey. Estimates of variance components, which better account for uncertainty due to sampling error and correlation between observations in the data sets were derived. These measures could be applied in weighting procedures for tuning age-sequential population dynamics models. In order to apply these procedures, which rely on external weights, in contrast to methods such as Maximum Likelihood fitting, an appropriate measure of the variance component of other tuning indices used in the assessment is also needed.

Introduction

Information on the relative abundance of king mackerel is required to tune stock assessment models. Data collected from several commercial and recreational fisheries and fisheries independent surveys have been previously used to develop standardized catch per unit effort (CPUE) indices of abundance for the Gulf of Mexico and South Atlantic king and Spanish mackerel stocks. This report documents alternative analytical methods applied to the available data through fishing year 2000 and presents standardized CPUE indices for king mackerel. These indices include estimates of variance which better account for sampling error and correlation between observations in the catch rate analyzed through the application of random effects modeling methods (Cooke, 1997). Catch and effort data collected from recreational fisheries surveys operating in the US Gulf of Mexico and the South Atlantic coast were used to develop the indices of abundance presented herein. Standardized catch rates were estimated using the Generalized Linear Mixed Model (GLMM) approach.

Materials and Methods

Legault *et al*. (2000) described the available catch and effort data for king mackerel from the recreational fisheries operating in the US Gulf of Mexico, while Legault *et al.* (1998) described the available catch and effort data for the Atlantic king mackerel stock. Powers et al (1996) described the conventional GLM for analysis of CPUE series. The present analysis is a modified application of GLM analysis, in which are included observations with fishing effort towards king mackerel, and also with zero catch (traditional standardization methods for many of the king and Spanish mackerel tuning indices only used records with positive catches for these species). At the 2001 Mackerel Stock Assessment Panel (MSAP), three recreational fisheries surveys data were reviewed and standardized: a) the MRFSS survey for charter and private recreational boats, b) the Headboat Survey of vessels operating in the US Gulf of Mexico and South Atlantic coast, and c) the Texas Parks and Wildlife Recreational Angler Creel Survey of vessels docked or operating off Texas coastal waters. As of April 2002, updated catch and effort data was available only for two of the surveys: a) the MRFSS survey and b) the Texas Parks and Wildlife Recreational Angler Creel Survey.

MRFSS. In 1996, the MSAP decided to include trips that indicated king mackerel as primary target species, even if they were unsuccessful. In the 1996 assessment analysis of MRFSS Florida Gulf CPUE data, the MSAP selected a Delta lognormal model with a lognormal error distribution for the proportion of positive trips. And, for the subset of positive catch trips, the Panel opted for adding the total catch per stratum (sum of catch per year-bimonth-mode-county cell), and used the number of trips per stratum as a weighing factor in the model specification (MSAP, 1996). To attempt to incorporate a fuller range of fishing effort that had reasonable probability of catching king mackerel in the analysis, the MRFSS intercept data were subset into effort that caught or indicated intent to catch a group of species believed to be associated with king mackerel in recreational fishery activities. The associated species used in these analyses were Spanish mackerel (*S. maculatus*), cero mackerel (*S. regalis*), greater amberjack (*Seriola dumerili*), banded rudderfish (*S. zonata*), almaco jack (*S. rivoliana*), little tunny (*Euthynnus alletteratus*), backfin tuna (*Thunnus atlanticus*), bonito (*Sarda sarda*) and wahoo (*Acanthocybium solanderi*).

Catch and effort information for 1981 through 2001 were available. Based on prior MSAP recommendations for the Gulf king stock, trips were restricted to the following: a) the months of July through December, b) the private/rental, or charter modes, and c) hook and line gear only. For the Atlantic king stock, trip restrictions included: a) the months of April through December, b) charter and private/rental modes, and c) hook and line gear only. Nominal indices were calculated as total number of fish caught (A+B1+B2) per thousand angler-hours fishing. In case of interviews where catch came from more than one angler, nominal CPUE was adjusted for non-interviewed anglers who contributed to catch by assuming similar catch to those anglers interviewed in a given trip or intercept. For the Gulf of Mexico king stock, intercepts from July through December were chosen to reduce the influence of trip limit regulation. Figure 1 shows the frequency distributions of log–transformed nominal CPUE of king mackerel successful trips. The explanatory variables considered for the MRFSS indices analysis included: year, bi-month (Mar-Apr, May-Jun, Jul-Aug, Sep-Oct, Nov-Dec), fishing mode (private/rental boats, charter boats, and shore), area (inshore, continental shelf 3 miles or less in the Atlantic coast, Louisiana, Mississippi and Alabama, 10 miles or less in the Florida Gulf coast, and offshore), and fishing target where target 1 specifically included king mackerel as targeted species, target 2 where other migratory coastal species where the main targets, and target 3 level where neither king mackerel or the other migratory species were the main targets.

There are currently minimum size and bag limit restrictions for both king and Spanish mackerel applying to recreational fisheries in the US Gulf of Mexico and Atlantic coast. These restrictions have been in effect since the 1986-87 fishing year for king mackerel stocks and since the 1987-1988 fishing year for Spanish mackerel (MSAP 1999). Bag limits have fluctuated among years between 2 and 5 fish for the Atlantic king stock, and also they varied among states. For the Gulf king stock, the bag limit has been more standard, varying between 2 and 3 fish. In these analyses, a bag limit factor was evaluated to account for these restrictions, but in general, the lack of contrast between year and bag-limit restrictions prevents the models from fully partitioning the effect due to the bag limit factor within a given year.

Texas Parks & Wildlife. The Texas Parks and Wildlife Department Recreational Angler Creel Survey data set includes catch and fishing effort information for both king and Spanish mackerel from 1983 through 2000. CPUE analysis for king mackerel was restricted to the summer months (May – September), the charter and private modes, and the offshore area. Only the major bay classification areas of Matagorda, San Antonio, Port Aransas, Corpus Christi, and lower Laguna Madre were also included. Inshore areas and passes were excluded from the present analyses, as king mackerel are not generally caught in these areas. The index is the standardized number of fish per thousand fishing hours. The explanatory variables considered include year, month, major bay, and area (nearshore <10 miles from shoreline, and offshore ≥10 miles). Figure 2 shows the frequency distribution of log transformed nominal CPUE for trips with successful king mackerel catch in the final data set.

Index Development.

Relative indices of abundance were estimated by GLMM approach assuming a delta lognormal model distribution. The present study used a delta model with a binomial error distribution for modeling the proportion of positive trips, and a lognormal assumed error distribution for modeling the mean density or catch rate of successful trips. Parameterization of the model used the GLM structure. The proportion of successful trips per stratum is assumed to follow a binomial distribution where the estimated proportion is a linear function of fixed factors and interactions. The logit function was used as link between the linear factor component and the binomial error. For successful trips, estimated CPUE rates are assumed to follow a lognormal distribution of a linear function of fixed factors and random effect interactions (in particular when the *Year* term was within the interaction).

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. The deviance difference between two consecutive model formulations follows a χ^2 (Chi-square) distribution. This statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponds to the number of degrees of freedom in the Chi-square test (McCullagh and Nelder, 1989). Deviance analysis tables are presented for all data set analyses, each table includes the deviance for the proportion of positive observations, and the deviance for the positive catch rates. Final selection of explanatory factors was conditional to: a) the relative percent of deviance explained by adding the factor in evaluation, normally factors that explained more than 5 to 10% of deviance were selected, b) the Chi-square test significance, and c) the type III test significance within the final specified model. Once a set of fixed factors was specified, possible 1st level interactions were evaluated, in particular random interactions between the year effect and other factors. In some cases, models with interactions did not converge to an acceptable solution and these were rejected. Analyses were done using the GLIMMIX and MIXED procedures from the SAS® statistical computer software (SAS Institute Inc. 1997, Littell *et al.* 1996).

Relative indices of abundance were estimated from each dataset as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components set. LSmeans estimates were weighted proportional to the observed margins in the input data due to the unbalanced characteristics of the data. For the lognormal LSmeans components, a log back-transformed bias correction was applied (Lo *et al*, 1992).

Results and Discussion

MRFSS dataset.

Deviance table analyses indicate that target is a main explanatory variable for catch rates of king mackerel in recreational fisheries. In both model components, the proportion of positive to total observations and the mean catch rate of successful trips, the target indicator accounts for a high percent of explained deviance (Table 1). Subsequent to target, area, by-month and mode were significant factors for king mackerel catch rates. Interaction random terms of year and area and by-month were significant in the case of king mackerel catch rates of positive observations (Table 2). Table 3 presents the standardized catch rates with 95% confidence intervals, coefficient of variance and number of observations per year in the analyzed data. Overall, coefficients of variance range from 21% to 54% for king mackerel Atlantic stock, and from 40% to 59% for king mackerel Gulf stock, respectively. Figure 3 shows the cumulative normalized deviance residuals or qq-plots for the final model of the positive observations fitting for both king mackerel stocks. Figure 4 shows the standardized CPUE series. For the Gulf king mackerel stock, there is not a clear trend, highest catch rate values corresponded to the 1991/92 and 1997/98 fishing year. In the case of the Atlantic king stock, highest catch rates corresponded to early years, 1981/82/83/84 and 1987/88, in recent years overall values are about 50 to 60% of the highest catch rates estimated.

Texas Parks & Wildlife Department Recreational Angler Creel Survey.

Table 4 shows the deviance analysis for king mackerel catch rates. The bay, area (nearshore, offshore) and month factors were the main explanatory variables. Figure 5 shows the cumulative normalized deviance residuals for the final model of the positive observations fitting for king mackerel Gulf stock. The interactions, particularly of year*bay, explained significant percent of the variability observed. The mixed model analysis indicated that year*month and area*bay interactions are also significant, in particular for king mackerel, reflecting the seasonal character for this species in the recreational fishery off Texas (Table 5). Table 6 and Figure 6 show the standardized catch rates for king mackerel Gulf stock.

Comparison of indices of abundance between data sets.

Figure 7 shows the standardized CPUE from the MRFSS and Texas PWD data sets, and the latest available Headboat standard series (Ortiz and Scott, 2001). All series were scaled to the mean of the common years for each stocks. In the case of Atlantic king, the series diverge mainly in the earlier years 1982/83. For the Gulf stock, the 3 series show general agreement in the latest years, showing overall above average catch rate values. The overall 95% confidence intervals overlap in all series, reflecting the uncertainty associated with the standardization procedures.

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Table 1 Analysis of deviance for the mean catch rate of successful observations and the proportion of positive to total observations for king mackerel from the MRFSS CPUE data. *p* value refers to the Chi-square probability test between two consecutive model formulations.

KING MACK GULF MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	1670.991			
year	15	1616.056	54.9	16.4%	< 0.001
year area	2	1516.469	99.6	29.7%	< 0.001
year area targ1	1	1484.989	31.5	9.4%	< 0.001
year area targ1 mode	1	1484.974	0.0	0.0%	0.903
year area targ1 mode bymonth	2	1483.9	1.1	0.3%	0.584
year area targ1 mode bymonth baglimt	1	1483.297	0.6	0.2%	0.437
year area targ1 mode bymonth baglimt year:area	22	1425.571	57.7	17.2%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1	15	1410.446	15.1	4.5%	0.442
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode	15	1383.262	27.2	8.1%	0.027
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode year:bymonth	29	1335.786	47.5	14.2%	0.017

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	7116.192			
year	15	6883.883	232.3	11.7%	< 0.001
year area	2	6616.5	267.4	13.5%	< 0.001
year area targ1	1	6280.908	335.6	17.0%	< 0.001
year area targ1 mode	1	5522.219	758.7	38.3%	< 0.001
year area targ1 mode bymonth	2	5483.963	38.3	1.9%	< 0.001
year area targ1 mode bymonth baglimt	1	5478.898	5.1	0.3%	0.024
year area targ1 mode bymonth baglimt year:area	30	5395.23	83.7	4.2%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1	15	5342.006	53.2	2.7%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode	15	5270.488	71.5	3.6%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode year:bymonth	29	5137.358	133.1	6.7%	< 0.001

KING MACK ATLANTIC MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	3311.113			
year	20	3244.272	66.8	11.5%	< 0.001
year area	2	3187.192	57.1	9.8%	< 0.001
year area targ1	1	3058.347	128.8	22.1%	< 0.001
year area targ1 mode	1	3058.295	0.1	0.0%	0.820
year area targ1 mode bymonth	4	2998.081	60.2	10.3%	< 0.001
year area targ1 mode bymonth baglimt	2	2937.138	60.9	10.5%	< 0.001
year area targ1 mode bymonth baglimt year:area	30	2909.565	27.6	4.7%	0.593
year area targ1 mode bymonth baglimt year:area year:targ1	20	2877.455	32.1	5.5%	0.042
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode	20	2854.134	23.3	4.0%	0.273
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode year:bymonth	72	2728.752	125.4	21.5%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	17776.73			
year	20	17614.34	162.4	5.6%	< 0.001
year area	2	17141.09	473.3	16.3%	< 0.001
year area targ1	1	15897.06	1244.0	42.7%	< 0.001
year area targ1 mode	1	15363.5	533.6	18.3%	< 0.001
year area targ1 mode bymonth	4	15283.62	79.9	2.7%	< 0.001
year area targ1 mode bymonth baglimt	2	15255.47	28.2	1.0%	< 0.001
year area targ1 mode bymonth baglimt year:area	40	15156.4	99.1	3.4%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1	20	15109.34	47.1	1.6%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode	20	15048.63	60.7	2.1%	< 0.001
year area targ1 mode bymonth baglimt year:area year:targ1 year:mode year:bymonth	75	14865.01	183.6	6.3%	< 0.001

Table 2. Analysis of delta lognormal mixed model formulations for king and Spanish mackerel catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models.

King mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Mode Targ1 Area Bymonth	1641.3	1643.3	1647.2		
Year Mode Targ1 Area Bymonth *Year*Bymonth*	1609.7	1613.7	1617.4	31.6	0.0000
Positive Catch					
Year Area Targ1 Mode Bymonth	4486.9	4488.9	4494.3		
Year Area Targ1 Mode Bymonth *Year*Area*	4464.8	4468.8	4472.2	22.1	0.0000
Year Area Targ1 Mode Bymonth *Year*Area Year*Targ1*	4464.8	4468.8	4472.2	0	1.0000
Year Area Targ1 Mode Bymonth *Year*Area Year*Targ2 Year*Mode*	4462.8	4470.8	4477.6	2	0.1573
Year Area Targ1 Mode Bymonth *Year*Area Year*Targ2 Year*Mode Year*Bymonth*	4451.8	4461.8	4470.2	11	0.0009

King mackerel Atlantic Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Targ1 Mode Area Bymonth	2724.7	2726.7	2731.3		
Year Targ1 Mode Area Bymonth *Year*Bymonth*	2718.2	2722.2	2727.4	6.5	0.0108
Positive Catch					
Year Targ1 Area Bymonth	9404.5	9406.5	9412.7		
Year Targ1 Area Bymonth *Year*Bymonth*	9381.2	9385.5	9390.6	23.3	0.0000
Year Targ1 Area Bymonth *Year*Bymonth Year*Targ1*	9377.8	9383.8	9391.5	3.4	0.0652

Table 3. King mackerel standardized catch rate, 95% confidence intervals and coefficient of variation from the MRFSS dataset. Index represents the scaled standard CPUE (fish/1000 hours) to the maximum value of the series.

King Atlantic stock

Year	N Obs	Nominal	Standardized	CV	Index	95% CI	
1981	100	48.722	42.162	53.0%	0.487	1.319	0.180
1982	145	95.861	79.773	33.5%	0.922	1.772	0.480
1983	161	114.964	86.501	32.8%	1.000	1.896	0.527
1984	136	64.727	41.528	40.3%	0.480	1.042	0.221
1985	90	74.511	32.953	54.2%	0.381	1.051	0.138
1986	383	80.996	33.163	29.1%	0.383	0.678	0.217
1987	784	119.750	61.043	23.3%	0.706	1.117	0.446
1988	1013	55.770	32.114	24.2%	0.371	0.598	0.230
1989	1017	43.339	27.944	24.2%	0.323	0.520	0.201
1990	1163	66.172	44.820	22.7%	0.518	0.811	0.331
1991	1249	62.244	41.596	23.1%	0.481	0.758	0.305
1992	1285	54.779	42.133	22.8%	0.487	0.763	0.311
1993	907	48.031	26.494	26.1%	0.306	0.512	0.183
1994	1167	28.624	19.179	26.1%	0.222	0.371	0.133
1995	992	48.407	30.730	25.4%	0.355	0.585	0.216
1996	1073	50.293	38.115	23.3%	0.441	0.698	0.278
1997	1217	65.409	50.655	22.3%	0.586	0.910	0.377
1998	1199	45.481	36.748	22.8%	0.425	0.666	0.271
1999	1524	56.061	42.351	21.8%	0.490	0.753	0.318
2000	1472	64.300	51.030	21.4%	0.590	0.901	0.386
2001	1359	46.951	39.642	22.4%	0.458	0.714	0.294

King Gulf stock

Year	N Obs	Nominal	Standardized	CV	Index	95% CI	
1986	465	26.282	15.904	53.0%	0.163	0.442	0.060
1987	395	84.563	57.907	47.1%	0.594	1.456	0.243
1988	298	69.304	45.322	46.8%	0.465	1.132	0.191
1989	238	60.401	33.715	49.8%	0.346	0.887	0.135
1990	162	95.019	89.367	50.5%	0.917	2.379	0.354
1991	196	158.137	97.430	45.8%	1.000	2.395	0.418
1992	281	125.513	73.258	46.2%	0.752	1.811	0.312
1993	307	61.318	49.499	43.6%	0.508	1.169	0.221
1994	246	86.157	49.010	47.1%	0.503	1.231	0.206
1995	155	50.719	38.412	58.3%	0.394	1.164	0.134
1996	262	59.442	68.822	48.1%	0.706	1.760	0.284
1997	452	140.676	87.893	42.3%	0.902	2.032	0.401
1998	769	63.225	54.214	41.7%	0.556	1.239	0.250
1999	750	103.861	58.094	40.9%	0.596	1.310	0.271
2000	827	129.506	70.218	39.1%	0.721	1.533	0.339

Table 4. Analysis of deviance for the mean catch rate of successful observations and the proportion of positive to total observations for king mackerel from the Texas Parks and Wildlife Division Recreational Angler Creel Survey data. *p* value refers to the Chi-square probability test between two consecutive model formulations.

TEXAS PWD DATA

GULF MEXICO KING MACKEREL

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	2525.5			
Year	17	2458.8	66.8	17.9%	< 0.001
Year Mode	1	2451.9	6.9	1.8%	0.009
Year Mode Area	1	2423.5	28.4	7.6%	< 0.001
Year Mode Area Bay	4	2403.7	19.8	5.3%	< 0.001
Year Mode Area Bay Month	4	2382.2	21.4	5.8%	< 0.001
Year Mode Area Bay Month Year*Mode	17	2361.9	20.3	5.4%	0.260
Year Mode Area Bay Month Year*Mode Year*Area	17	2349.8	12.1	3.2%	0.796
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area	1	2349.8	0.0	0.0%	0.987
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay	68	2256.3	93.6	25.1%	0.022
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay	4	2253.9	2.4	0.6%	0.663
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay	4	2240.6	13.3	3.6%	0.010
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month	64	2185.2	55.4	14.9%	0.771
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month Mode*Month	4	2176.7	8.5	2.3%	0.075
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month Mode*Month Area*Month	4	2162.2	14.5	3.9%	0.006
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month Mode*Month Area*Month Bay*Mo	16	2153.3	8.9	2.4%	0.917

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	2687.7			
Year	17	2544.2	143.48	9.6%	< 0.001
Year Mode	1	2434.7	109.53	7.4%	< 0.001
Year Mode Area	1	2362.3	72.43	4.9%	< 0.001
Year Mode Area Bay	4	2131.5	230.77	15.5%	< 0.001
Year Mode Area Bay Month	4	1892.4	239.07	16.1%	< 0.001
Year Mode Area Bay Month Year*Mode	17	1852.4	40.08	2.7%	0.001
Year Mode Area Bay Month Year*Mode Year*Area	17	1816.9	35.42	2.4%	0.005
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area	1	1811.4	5.51	0.4%	0.019
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay	68	1582.4	229.02	15.4%	< 0.001
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay	4	1574.5	7.92	0.5%	0.095
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay	4	1475.7	98.78	6.6%	< 0.001
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month	66	1266.7	209.05	14.0%	< 0.001
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month Mode*Month	4	1262.5	4.11	0.3%	0.391
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month Mode*Month Area*Month	4	1258.5	4.01	0.3%	0.404
Year Mode Area Bay Month Year*Mode Year*Area Mode*Area Year*Bay Mode*Bay Area*Bay Year*Month Mode*Month Area*Month Bay*Mo	16	1199.3	59.26	4.0%	< 0.001

Table 5. Analysis of delta lognormal mixed model formulations for king mackerel catch rates from the TPWD recreational angler creel survey data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models

Texas PWD

King mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Mode Area Bay Month	3579	3581	3585.9		
Year Mode Area Bay Month *Year*Month*	3559.1	3563.1	3568	19.9	0.0000
Year Mode Area Bay Month *Year*Month Year*Bay*	3554.9	3560.9	3568.3	4.2	0.0404
Year Mode Area Bay Month *Year*Month Year*Bay Area*Bay*	3528.7	3536.7	3546.6	26.2	0.0000
Positive Catch					
Year Area Bay Month Mode	8709.3	8711.3	8717.5		
Year Area Bay Month Mode *Year*Bay*	8686	8690	8695	23.3	0.0000
Year Area Bay Month Mode *Year*Bay Year*Mode*	8681.5	8687.5	8695	4.5	0.0339

Table 6. King mackerel standardized catch rates, 95% confidence intervals and coefficient of variance from the TPWD Recreational Angler Creel Survey data.

King Gulf.

Year	N Obs	Nominal	Standardized	CV	Index	95% CI	
1983	616	80.808	63.217	28.0%	0.842	1.458	0.486
1984	1020	74.137	62.321	28.1%	0.830	1.440	0.478
1985	766	75.243	52.279	28.7%	0.696	1.222	0.396
1986	514	33.070	23.396	32.7%	0.311	0.589	0.165
1987	524	47.965	44.504	29.7%	0.592	1.061	0.331
1988	437	48.579	35.589	30.1%	0.474	0.853	0.263
1989	357	53.742	38.322	31.3%	0.510	0.941	0.277
1990	481	35.302	30.734	31.5%	0.409	0.757	0.221
1991	421	78.235	75.116	28.1%	1.000	1.735	0.576
1992	390	61.991	53.818	30.3%	0.716	1.296	0.396
1993	411	62.608	48.958	31.1%	0.652	1.197	0.355
1994	355	66.936	49.702	30.4%	0.662	1.199	0.365
1995	494	63.586	53.021	29.8%	0.706	1.266	0.394
1996	484	73.359	60.976	28.7%	0.812	1.426	0.462
1997	501	72.179	43.382	32.0%	0.578	1.079	0.309
1998	723	76.239	56.256	30.5%	0.749	1.360	0.413
1999	614	66.995	46.496	32.2%	0.619	1.160	0.330
2000	547	47.930	35.654	34.2%	0.475	0.924	0.244

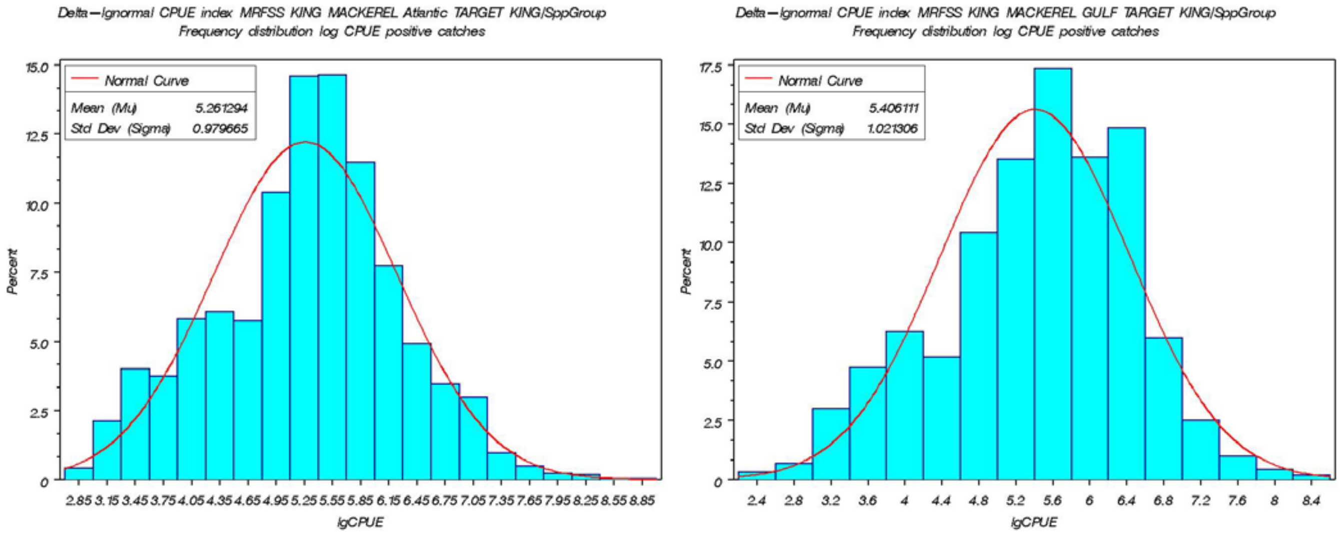


Figure 1. Frequency distribution of king mackerel log-transformed nominal CPUE of positive observations from the MRFSS dataset (number of fish per 1000 angler-hour fishing). Smooth line represents the estimated normal curve for each distribution.

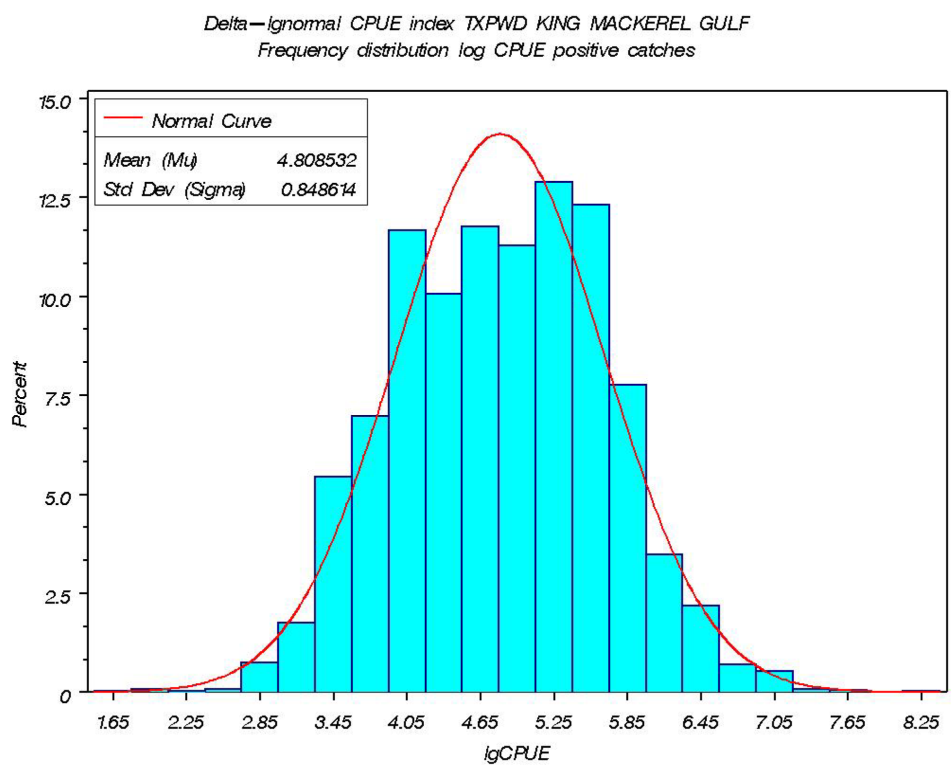


Figure 2. Frequency distribution of king mackerel log-transformed nominal CPUE of positive observations from the Texas Parks and Wildlife Division Recreational Angler Creel Survey
(number of fish per 1000 angler-hour fishing).

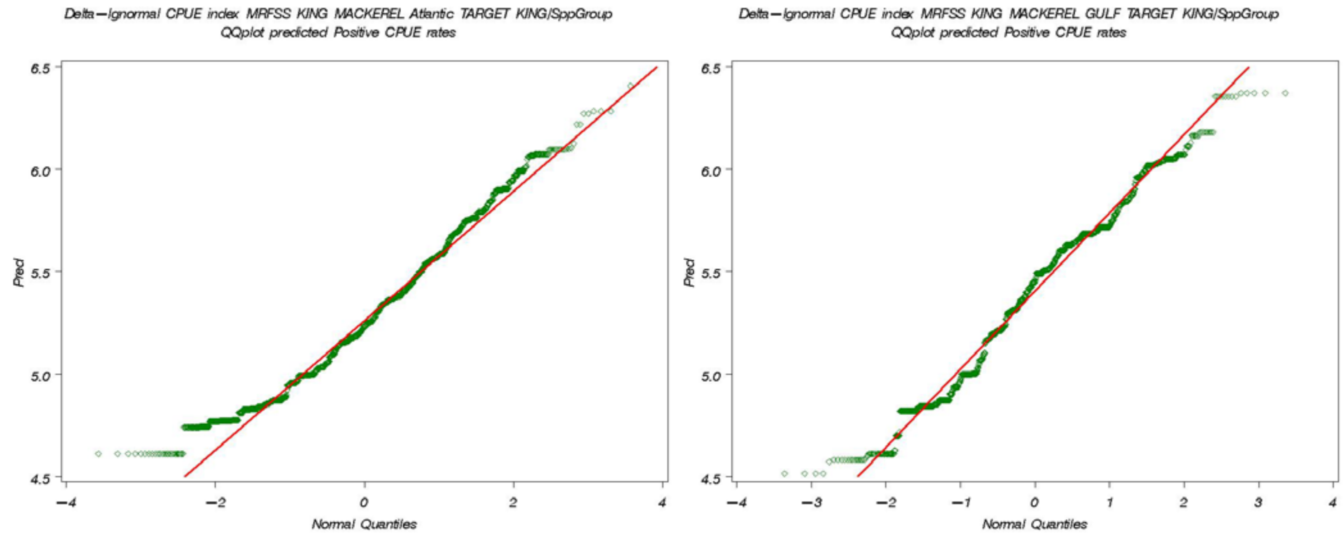
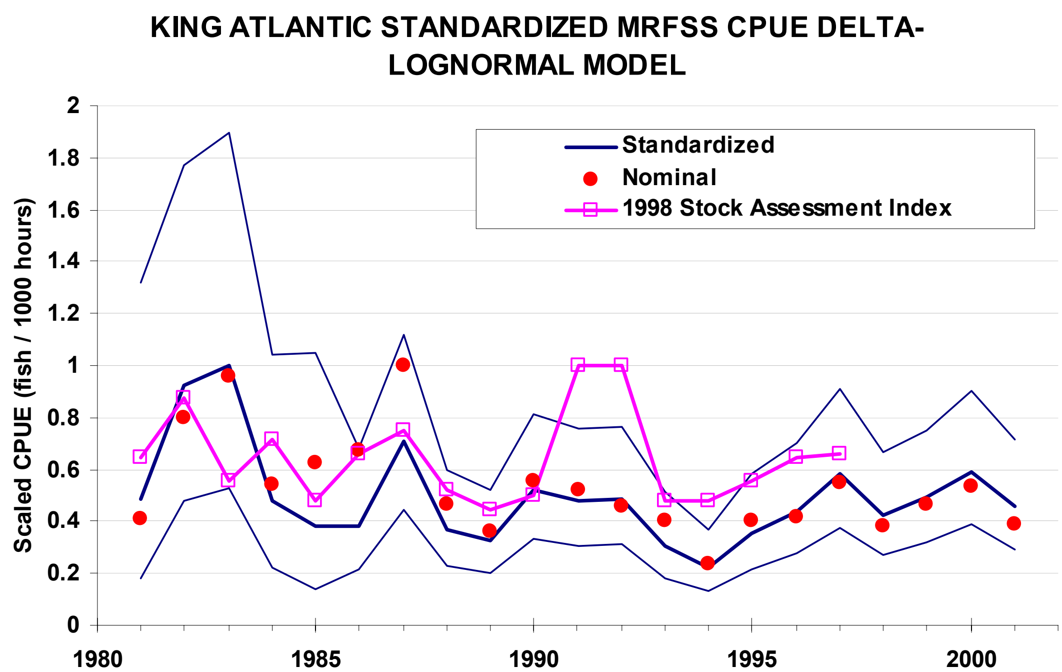


Figure 3 qq-plots of deviance residuals from the delta lognormal model fit of positive observations for king mackerel Atlantic (left) and Gulf (right) stocks, MRFSS dataset.



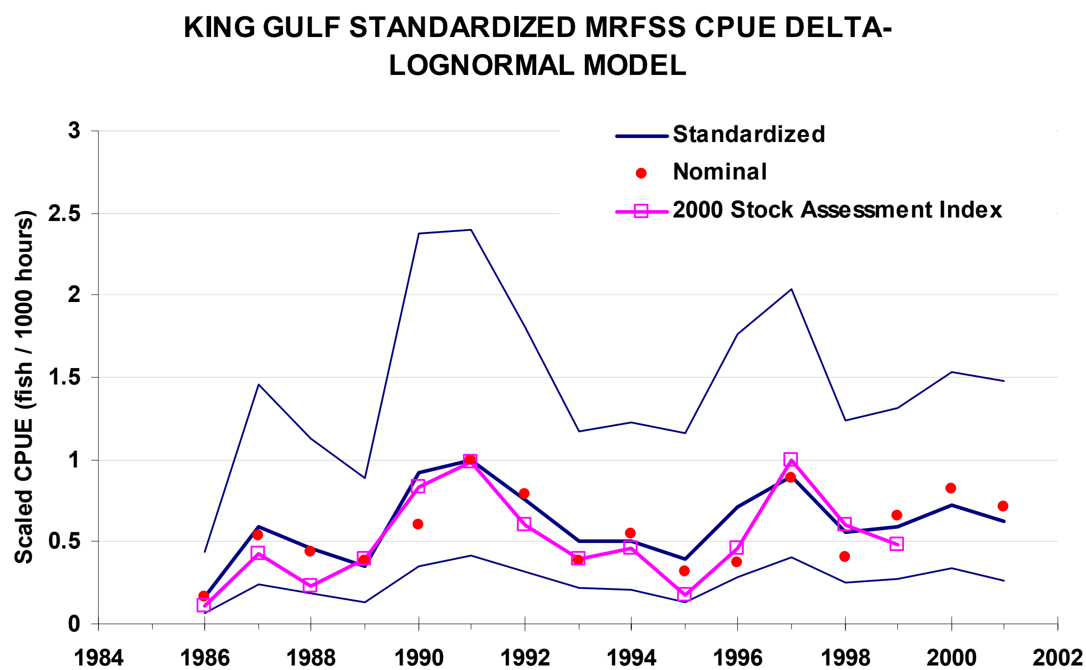


Figure 4 Nominal and standardized CPUE series for king mackerel Atlantic (top) and Gulf (bottom) stocks. Thin lines represent estimated 95% confidence intervals.

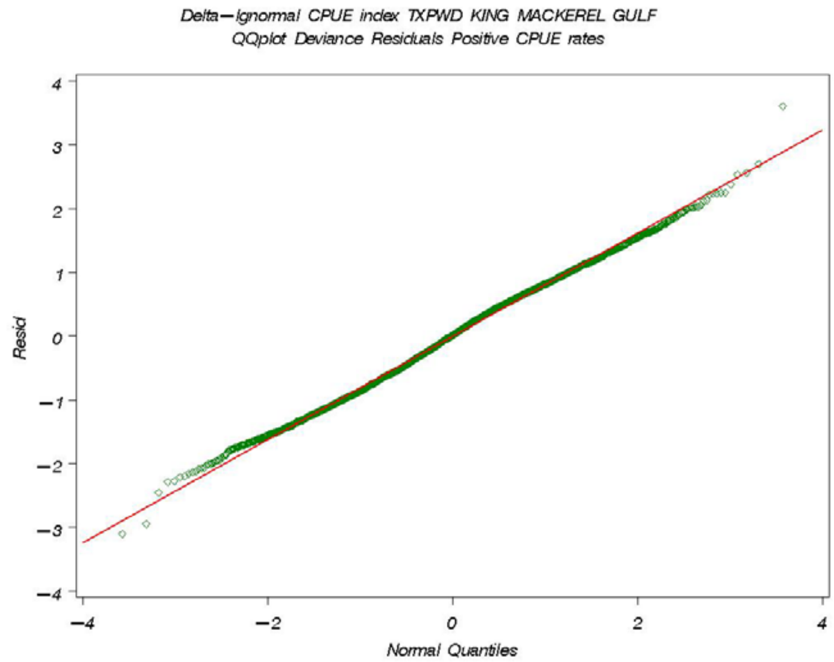


Figure 5 qq-plot of deviance residuals from the delta lognormal model fit of positive observations for king mackerel Gulf stock, TPWD dataset.

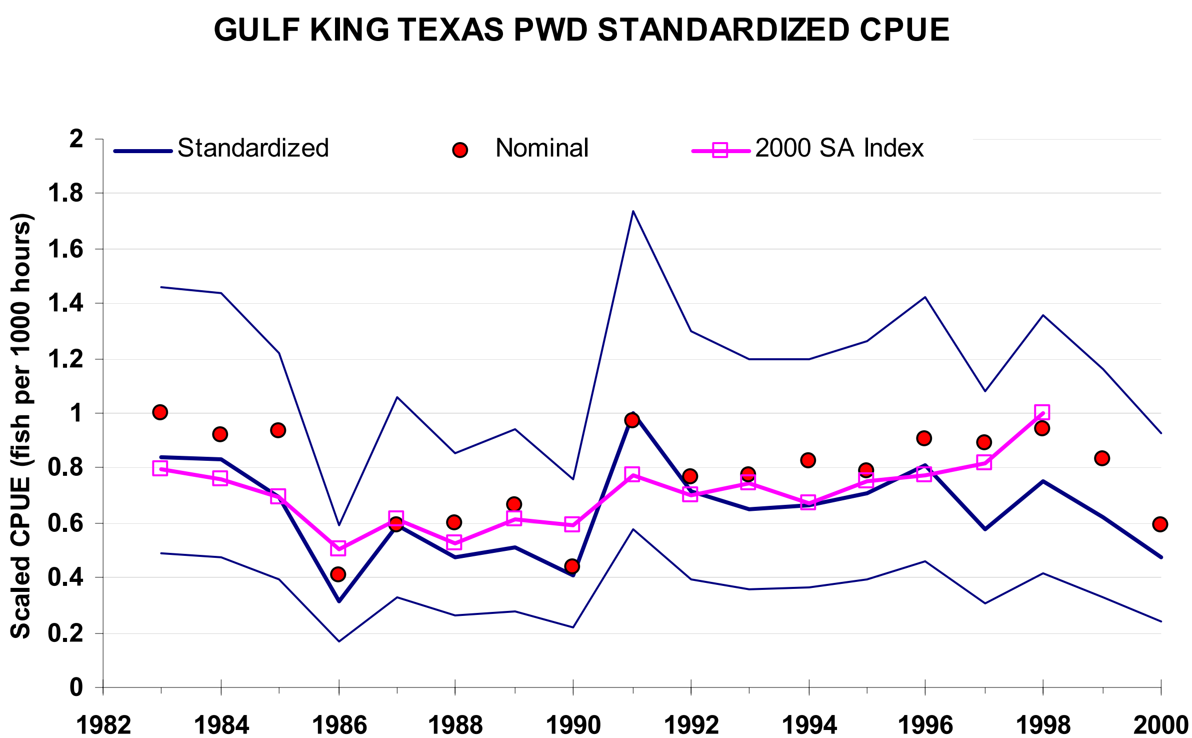
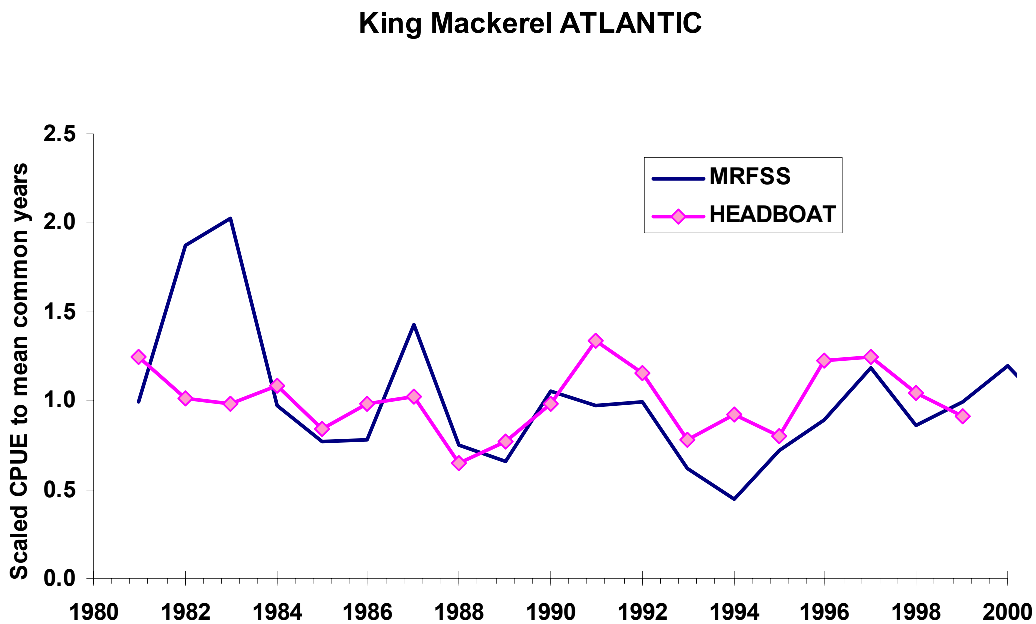


Figure 6. Nominal and standardized CPUE series for king mackerel Gulf stock from the TPWD. Thin lines represent estimated 95% confidence intervals.



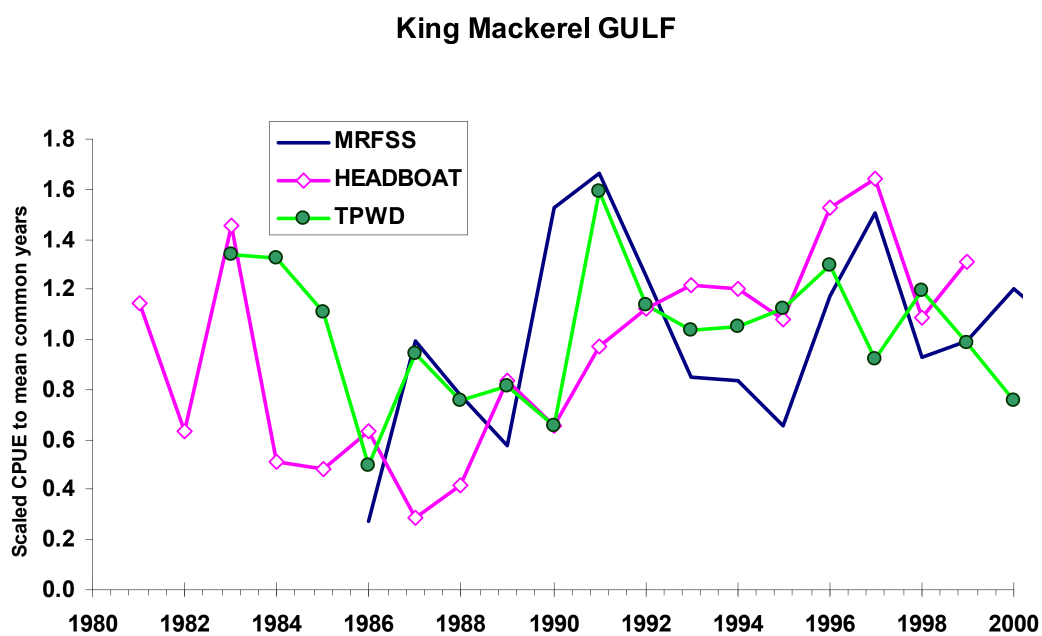


Figure 7. Comparison of standard CPUE series for king mackerel Atlantic and Gulf stocks from recreational fisheries data. (Headboat CPUE series is the 2001 available index).