Updated standardized catch rates of king mackerel (Scomberomorus cavalla) from the headboat fishery in the U.S. Gulf of Mexico and U.S. South Atlantic

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SEDAR38-DW-16

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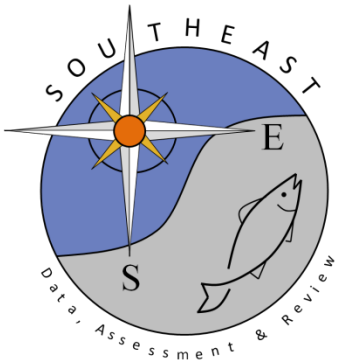
**ADDENDUM ADDED TO REFLECT CHANGES REQUESTED DURING THE DATA WORKSHOP. PLEASE SEE ADDENDUM FOR FINAL DETAILS. (PDF PAGE 17)*



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UPDATED STANDARDIZED CATCH RATES OF KING MACKEREL (*SCOMBEROMORUS CAVALLA*) FROM THE HEADBOAT FISHERY IN THE U.S. GULF OF MEXICO AND U.S. SOUTH ATLANTIC

Matt Lauretta and Shannon L. Cass-Calay[1]

SUMMARY

Indices of abundance of king mackerel from the United States headboat fishery in the Gulf of Mexico and the U.S. South Atlantic are presented for the period 1980-2012. All were standardized using Generalized Linear Mixed Models, and a delta-lognormal approach. Two updated indices were constructed using the SEDAR 16 methods and area definitions. These are intended to be used during continuity case assessment models. Updated indices were constructed for the U.S. Gulf of Mexico and the U.S. South Atlantic, excluding samples from the winter mixing zone. The analysis used a repeated measures approach on fishing vessels that fished for at least 10 years to account for the variance in catch rates between vessels. Additionally, data were restricted to trips that fished in the habitat of king mackerel, with trip selection based on species composition of co-occurring species.

KEY WORDS

Catch/effort, abundance, headboat, multivariate analyses

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1. INTRODUCTION

Rod and reel catch and effort from party (head) boats have been monitored by the NMFS Southeast Zone Headboat Survey (conducted by the NMFS Beaufort Laboratory) since 1973 in the U.S. South Atlantic and 1986 in the U.S Gulf of Mexico. The Headboat Survey collects data on the catch and effort for a vessel trip. Reported information includes landing date and location, vessel identification, the number of anglers, fishing location, trip duration and/or type (half/three-quarter/full/multi-day, day/night, morning/afternoon), and catch by species in number and weight. These data were used to construct standardized catch rate indices for king mackerel in the U.S. South Atlantic and Gulf of Mexico and as defined by the SEDAR 16 assessment panel.

2. MATERIALS AND METHODS

Two indices, one each for the Atlantic and Gulf of Mexico migratory groups, were constructed using the methods employed during the previous assessment (Cass-Calay 2008). The following factors were previously determined to influence the proportion positive trips, the catch rates on positive trips, or both, and the continuity indices used these same set of factors:

1) ATLANTIC INDEX		
FACTOR	**LEVELS**	**DESCRIPTION**
YEAR	28	1979 – 2006
SEASON	4	Jan – Mar Apr – Jun, Jul –Oct Nov-Dec
AREA	10	1 = Cape Hatteras Offshore
		2 = Cape Fear Inshore
		3 = Cape Fear Offshore
		4 = South Carolina Inshore
		5 = South Carolina Offshore
		6 = Georgia
		7 = NE Florida ***IF LATITUDE ≥ 29°N or Unreported***
		8 = East Central Florida ***IF LATITUDE ≥ 29°N***
		9 = Cape Lookout Inshore
		10 = Cape Lookout Offshore
VESSEL		Analyzed using "Repeated Measures" approach

2) GULF INDEX		
FACTOR	**LEVELS**	**DESCRIPTION**
YEAR	21	1986 – 2006
SEASON	4	Jan – Mar Apr – Jun, Jul –Oct Nov-Dec
AREA	7	21 = Naples/Crystal River ***IF LATITUDE ≥ 26°N or Unreported***
		22 = FL Middle Grounds
		23 = NW Florida and Alabama
		24 = Louisiana
		25 = NE Texas - Sabine/Freeport
		26 = Central Texas - Port Aransas
		27 = South Texas - Port Isabel
VESSEL		Analyzed using "Repeated Measures" approach

The variable "Hours Fished" does not exist in the dataset. To estimate the number of hours fished, the following assumptions were necessary (Ortiz, 2003).

TRIP CODE	DEFINITION	HOURS FISHED
21,29	½ day, in PM	6
23	¾ day (2nd trip)	9
1,9	½ day, in AM or at night	3
3	¾ day	4.5
2,4	Full day or Overnight	6
25	1½ days	9
5	Two days	12
6	Three days	18
7	Four days	24
8	Five days	30
10	Six days	36
11	Seven days	42

Catch rate (CPUE) on positive trips was calculated in number of fish per 1000 angler hours.

CPUE = 1000 *{number of fish / (anglers * hours fished)}

Modeling of Vessel Effects

Three regions were considered: 1) the Atlantic, 2) the "Mixing Area" and 3) the Gulf of Mexico. The indices described in this section were constructed using the calendar year. No adjustment was made to accommodate the "fishing year" definitions to be consistent with the SEDAR 16 base model. Areas 13, 14, 15 and 16 were excluded from these analyses, either because they are not used (14,15,16) or because they are outside U.S. jurisdiction (13)**.** Trips prior to 1979 were excluded since they almost never report landing king mackerel. Trips longer than 24 hours *were not* excluded from these analyses.

The variation in catch rates by VESSEL was examined using a "repeated measures" approach (Little et al., 1998). The term "repeated measures" refers to multiple measurements taken over time on the same experimental unit (i.e. vessel). Specifying the repeated measure "VESSEL" and the subject "VESSEL(YEAR)" allows PROC MIXED to model the covariance structure of the data. This is particularly important because catch rates may vary by vessel *and because* catch rates on trips by a given vessel close in time can be more highly correlated that those far apart in time (Littell et al., 1998).

Selection of Trips Using Species Composition

A data filtering technique was used to restrict the dataset to trips that fished in the habitat of king mackerel. In the absence of direct information useful to infer targeting (e.g. depth of fishing, fine-scale fishing location, bottom type, gear configuration), an objective approach developed by Stephens and McCall (2004) was used to subset trip records using species composition. A brief summary of the methodology follows (***adapted from Stephens and McCall, 2004):***

First, the species composition from catch records was used to estimate the parameters of a logistic regression. For example, let Y_j be a categorical variable describing the presence/absence of the non-target species for trip j. Similarly, let x_{ij} describe the presence/absence of king mackerel.

$$Y_j = \begin{cases} 1 & \text{if the target species is caught} \\ 0 & \text{if the target species is not caught} \end{cases}$$

Then a logistic regression was applied to estimate the probability that king mackerel would have been encountered on a trip. Using the regression results, a score (S_j) was assigned to each trip j as a function of the species encountered on that trip:

$$S_j = \exp \sum_{i=0}^{k} x_{ij}\beta_i$$

where the coefficients $\beta_1,\beta_2,\ldots\beta_k$ quantify the predictive effect of each species and β_0 is the intercept of the logistic regression.

This score was then converted into the probability of observing king mackerel given the vector of presence/absence of the other species observed on the trip (j).

$$\pi_j = \Pr\{Y_j = 1\} = \frac{S_j}{1 + S_j}$$

Given the coefficients β_0, β_1, . . ., β_k and the presence/absence indicators x_{1j},..., x_{kj}, the log-likelihood (excluding constants independent of the parameters) is the sum:

$$L\{Y|\beta_0, \ldots, \beta_k, x_{1j}, \ldots, x_{kj}\} = \sum_{j \in j+} \log(\pi_j) + \sum_{j \in j-} \log(1 - \pi_j)$$

where j+ indicates trips that observed king mackerel, and j- indicates trips that did not observe king mackerel. The log-likelihood was maximized using the statistical package R (Ihaka and Gentleman, 1996). The estimated β coefficients reflect the association (positive or negative) between the non-target species and king mackerel, π_j is intended to estimate the probability that the trip *j* fished in the habitat of king mackerel.

Trip records were selected for CPUE analysis using a critical value. The critical value was determined by examining the relationship between the critical value and the number of incorrect predictions. Both false positives (king mackerel predicted to occur when absent) and false negatives (king mackerel not expected to occur when present) were considered. The critical value that minimized the number of incorrect predictions was selected. Trip records were included in the CPUE analysis if π (as calculated above) was above the critical value.

Recreational Fishery Regulations

King mackerel recreational landings are managed using three types of fishing regulations, minimum size limits, bag limits and fishing closures. These vary by year and management region (ATL, GOM), and are summarized in **Table 1**. Analyses undertaken to examine the effects of management regulations on fisheries dependent indicators, including the HB indices, are described in SEDAR16-AW-02.

A) Bag Limits: Although various bag limits have been mandated during the time series (**Table 1**), it was determined during SEDAR 16 that no significant effect of the bag limit was found for the Atlantic or headboat fisheries. This result agrees with the testimony of headboat captains present at the SEDAR16 DW. They reported that catches of king mackerel (on headboat trips) were not often restricted by the bag limit since the individual bag limit is multiplied by the large number of anglers on board. The continuity indices were constructed under this same assumption.

B) Size Limits: The SEDAR 16 working group recommended that changes in selectivity caused by increasing the minimum size limit be estimated by the SS3 model directly. Therefore, they did not recommend breaking the indices at the changes in size limit. Previous king mackerel

assessments did not break the indices at the changes in size limit. Therefore, the continuity indices were constructed as unbroken time-series.

C) Fishing Closures: Several fishing closures were enacted during the time-series (**Table 1.**) According to regulation §622.43 paragraph (a)(3)(ii), a person aboard a vessel for which valid charter vessel/headboat permits for Gulf coastal migratory pelagic fish or South Atlantic coastal migratory pelagic fish and a valid commercial vessel permit for king or Spanish mackerel have been issued may continue to retain fish under a bag and possession limit specified in § 622.39(c), provided the vessel is operating as a charter vessel or headboat. However, sale of the closed species is prohibited. No data was presented to the SEDAR16 DW to determine which headboat vessels also possessed a commercial permit during the time-series, nor is it clear whether these boats fish in the same manner during open and closed seasons. For these reasons, all trips that occurred during recreational fishing closures were excluded from the analyses.

3. RESULTS AND DISCUSSION

Table 2 and **Table 3** list the model factors determined to be significant during SEDAR 16, and these same set of factors were used to generate the SEDAR 38 continuity indices. Continuity indices demonstrated similar fit to the observed catch rate data as the previous assessment base indices, indicating the model structure and assumptions used in SEDAR 16 were effectively reproduced (**Figures 1 and 2**). Catch indices of King mackerel in the Atlantic Ocean indicated a sharp and steady decline since 2007, with the standardized index for 2012 predicted to be the lowest of the time series (**Table 4, Figure 1**). Catch indices of King mackerel in the Gulf of Mexico indicated a more stable trend over the last decade (**Table 5, Figure 2**), with recent indices near or greater than the mean observed across the time series. Model fit diagnostics indicated a good fit of the normal probability distribution to the observed data near the distribution center, but a lack-of-fit to the upper and lower quantiles of the data (**Figure 3**). Model residuals were approximately normal, with the exception of few outliers in which the model demonstrated a strong negative bias in predictions (**Figure 3**), although these outliers represented a few data points. Kilmogorov-Smirnov goodness-of-fit tests (KS test) on the data quantiles (0 quantile to the 100^{th} quantile, by increments of one percent) indicated that the distribution of the log-transformed positive catch rate data were not significantly different from a normal probability model in both the Atlantic (KS test p-value >0.9) and the Gulf of Mexico (KS test p-value = 0.7).

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Table 1. King Mackerel recreational fishing regulations.

	Fishing Year			Bag Limit		Closures	
Year	Atlantic	Gulf	Size Limit	Atlantic	Gulf	Atlantic	Gulf
1983-1984[1]			--	--	--	--	--
1984-1985[1]			--	--	--	--	--
1985-1986[2]	4/1 - 3/31	7/1 - 6/30	--	--	--	--	--
1986-1987	4/1 - 3/31	7/1 - 6/30	--	Private = 2/person/trip; Charterboat = greater of 2/person incl capt&crew or 3/person excl capt&crew		--	--
1987-1988	4/1 - 3/31	7/1 - 6/30	--	3/person/trip	"		Closed 12/16/87 0100h Reopened 7/1/1988 0001h
1988-1989	4/1 - 3/31	7/1 - 6/30	--	2/person/trip FL & 3 GA to NC	"	Closed 10/17/88 0100h Reopened 4/1/89 0001h	Closed 12/17/88 0001h Reopened 7/1/1989 0001h
1989-1990	4/1 - 3/31	7/1 - 6/30	--	2/person/trip FL & 3 GA to NC	"		
1990-1991[3]	4/1 - 3/31	7/1 - 6/30	12 in FL or 14 in TL	2 FL; 3 GA-NY	Same as above[4]		Closed 12/20/90 0001h Reopened 7/1/1991 0001h
1991-1992	4/1 - 3/31	7/1 - 6/30	12 in FL or 14 in TL	5 FL-NY	"		Closed 01/13/92 Reopened 7/1/1992
1992-1993	4/1 - 3/31	7/1 - 6/30	20 in FL	2 FL; 5 GA-NY	2 per person including captain & crew		--
1993	Calendar Year		20 in FL	"	"		--
1994	Calendar Year		20 in FL	"	"		--
1995	Calendar Year		20 in FL	2 FL; 3 GA-NY	"		--
1996	Calendar Year		20 in FL	"	"		--
1997	Calendar Year		20 in FL	"	2 per person, 0 capt&crew as of 6-97		--
1998	Calendar Year		20 in FL	"	2 per person, 2 capt&crew as of 2-98		--

Table 1 Cont. King Mackerel recreational fishing regulations.

1999	Calendar Year	24 in FL	"	2 per person, 0 capt&crew as of 9-99	--
2000-2012	Calendar Year	24 in FL	"	2 per person, 2 capt&crew as of 6-00	--

[1]One stock

[2]Two management groups (Atlantic & Gulf migratory) from this point forward

[3]Management area expands from TX through NC to TX through NY

[4]Redefined as daily bag limits; 1-day possession except for-hire on multi-day can have 2-day possession

Table 2. SEDAR 16 analysis of the mixed model formulations of King mackerel indices with Species Composition –Atlantic Region. The selected models are indicated with gray shading and were used in the SEDAR 38 continuity update.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Area+ Year + Season	**67957.8**	**67959.8**	**67967.5**	**-**	**-**
Area+ Year + Season + Year*Area			Did not converge		
Area+ Year + Season + Year*Season			Did not converge		

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Area + Year + Season + Area*Season	22453.8	22455.8	22462.7	-	-
Area + Year + Season + Area*Season + Year*Area	22282.6	22286.6	22292.9	171.2	<0.0001
Area + Year + Season + Area*Season + Year*Area + Year*Season	22262.5	22268.5	22277.9	20.1	<0.0001
Area + Year + Season + Area*Season + Vessel(Year)	19212.9	19216.9	19225.6	3240.9	<0.0001
Area + Year + Season + Area*Season + Vessel(Year) + Year*Area			Did not converge		
Area + Year + Season + Area*Season + Vessel(Year) + Year*Season	**19174.4**	**19180.4**	**19188.2**	**38.5**	**<0.0001**

Table 3 . Analysis of the mixed model formulations of the SEDAR 16 Indices with Species Composition – Gulf Region. The final selected models are indicated with gray shading and were used for the SEDAR 38 continuity update.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Season + Area + Year	**9127.5**	**9129.5**	**9135.2**	**-**	**-**
Season + Area + Year + Year*Season	9351.5	9355.5	9360.4	-224.0	1.0000
Season + Area + Year + Year*Area	9128.3	9132.3	9138.1	-0.8	1.0000

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Area + Season + Year	63142.0	63144.0	63151.8	-	-
Area + Season + Year + Year*Area	62562.2	62566.2	62571.8	579.8	<0.0001
Area + Season + Year + Year*Area + Year*Season	62434.6	62440.6	62449.1	127.6	<0.0001
Area + Season + Year + Vessel(Year)	59569.7	59573.7	59582.9	3572.3	<0.0001
Area + Season + Year + Vessel(Year) + Year*Area			Not Convergent		
Area + Season + Year + Vessel(Year) + Year*Season	**59374.2**	**59380.2**	**59387.3**	**3060.4**	**<0.0001**

Table 4. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the U.S. South Atlantic Ocean (non-mixing).

Year	n	Obs_CPUE	Obs_Prop_Pos	Standardized_CPUE	95%_CI_LL	95%_CI_UL	CV
1980	132	7.02	0.37	0.60	0.25	1.40	0.45
1981	101	8.21	0.34	1.45	0.56	3.76	0.50
1982	168	3.53	0.41	0.63	0.23	1.69	0.53
1983	249	4.41	0.55	1.58	0.76	3.30	0.38
1984	292	8.32	0.59	0.91	0.50	1.67	0.31
1985	321	3.34	0.44	0.57	0.31	1.05	0.31
1986	447	4.96	0.42	0.60	0.37	0.98	0.25
1987	615	8.25	0.45	0.81	0.50	1.32	0.25
1988	461	5.35	0.51	0.83	0.50	1.37	0.25
1989	250	2.64	0.41	0.49	0.27	0.88	0.30
1990	359	2.97	0.41	0.65	0.35	1.21	0.31
1991	532	16.01	0.59	1.32	0.80	2.18	0.25
1992	674	13.96	0.63	1.71	1.07	2.75	0.24
1993	758	9.62	0.50	0.76	0.47	1.24	0.25
1994	695	5.83	0.41	0.60	0.36	1.00	0.26
1995	765	5.22	0.42	0.70	0.43	1.13	0.25
1996	655	6.17	0.35	0.48	0.28	0.81	0.27
1997	545	17.91	0.45	1.08	0.66	1.76	0.25
1998	754	30.76	0.54	1.36	0.87	2.14	0.23
1999	684	10.10	0.47	1.04	0.65	1.66	0.24
2000	835	35.88	0.61	1.91	1.23	2.97	0.22
2001	642	21.03	0.52	1.43	0.90	2.28	0.23
2002	608	16.16	0.48	0.91	0.55	1.52	0.26
2003	456	27.19	0.51	0.98	0.60	1.59	0.25
2004	619	27.94	0.39	1.03	0.63	1.67	0.25
2005	459	21.42	0.53	1.34	0.79	2.28	0.27
2006	584	29.33	0.53	1.25	0.79	2.00	0.24
2007	676	22.73	0.59	1.49	0.94	2.37	0.23
2008	472	21.79	0.44	1.20	0.75	1.92	0.24
2009	581	22.07	0.47	1.27	0.79	2.05	0.24
2010	500	15.36	0.38	0.87	0.50	1.49	0.28
2011	418	21.55	0.39	0.70	0.40	1.21	0.28
2012	378	7.31	0.34	0.44	0.24	0.80	0.30

Table 5. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the Gulf of Mexico (non-mixing).

Year	n	Obs_Prop_Pos	Obs_CPUE	Standardized_CPUE	95%_CI_LL	95%_CI_UL	CV
1986	966	0.52	29.60	0.71	0.50	1.00	0.17
1987	1098	0.49	23.92	0.66	0.48	0.92	0.17
1988	701	0.57	36.83	0.79	0.54	1.14	0.19
1989	801	0.59	42.41	0.81	0.57	1.16	0.18
1990	1471	0.42	25.09	0.55	0.40	0.76	0.16
1991	860	0.64	33.96	1.29	0.96	1.75	0.15
1992	1167	0.63	44.80	1.20	0.90	1.60	0.15
1993	1599	0.49	28.84	0.86	0.65	1.14	0.14
1994	2038	0.58	29.67	1.16	0.90	1.49	0.13
1995	2064	0.62	38.36	1.27	0.99	1.64	0.13
1996	1676	0.63	40.39	1.39	1.06	1.81	0.13
1997	1109	0.55	25.58	1.16	0.85	1.58	0.16
1998	1875	0.57	31.67	1.04	0.79	1.37	0.14
1999	1074	0.47	29.00	0.95	0.69	1.31	0.16
2000	1776	0.55	31.86	0.88	0.66	1.17	0.14
2001	1643	0.53	33.37	0.69	0.52	0.93	0.15
2002	1978	0.53	30.71	0.73	0.55	0.96	0.14
2003	1647	0.61	44.61	1.00	0.75	1.33	0.14
2004	1559	0.55	38.05	0.67	0.50	0.91	0.15
2005	1495	0.59	48.35	1.01	0.75	1.37	0.15
2006	1851	0.67	48.49	1.28	0.97	1.69	0.14
2007	1550	0.63	47.85	1.18	0.89	1.56	0.14
2008	854	0.50	26.11	1.07	0.78	1.46	0.16
2009	1871	0.65	39.50	1.57	1.22	2.02	0.13
2010	1240	0.59	44.37	0.95	0.69	1.31	0.16
2011	1394	0.64	46.40	1.15	0.87	1.51	0.14
2012	1958	0.63	30.51	0.97	0.75	1.26	0.13

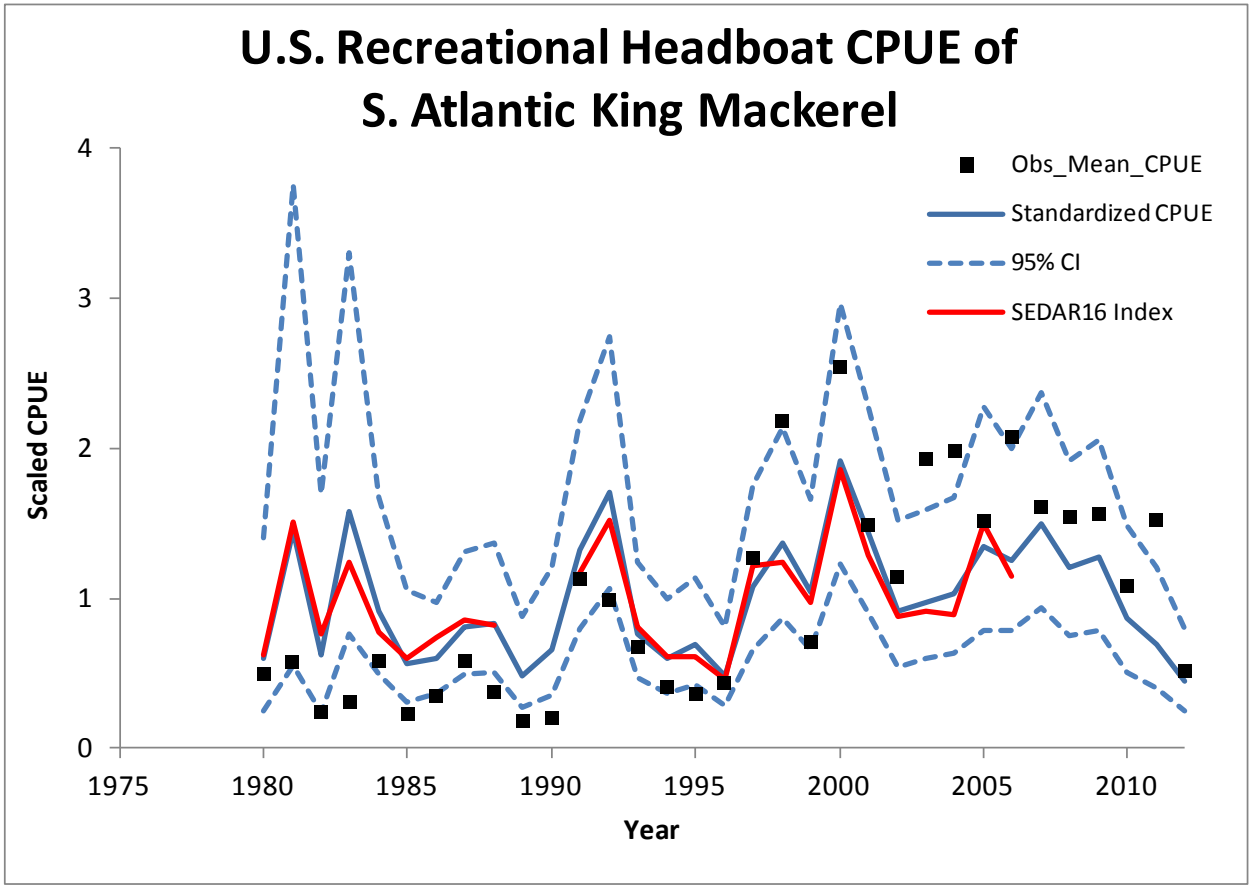

Figure 1. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the South Atlantic (non-mixing).

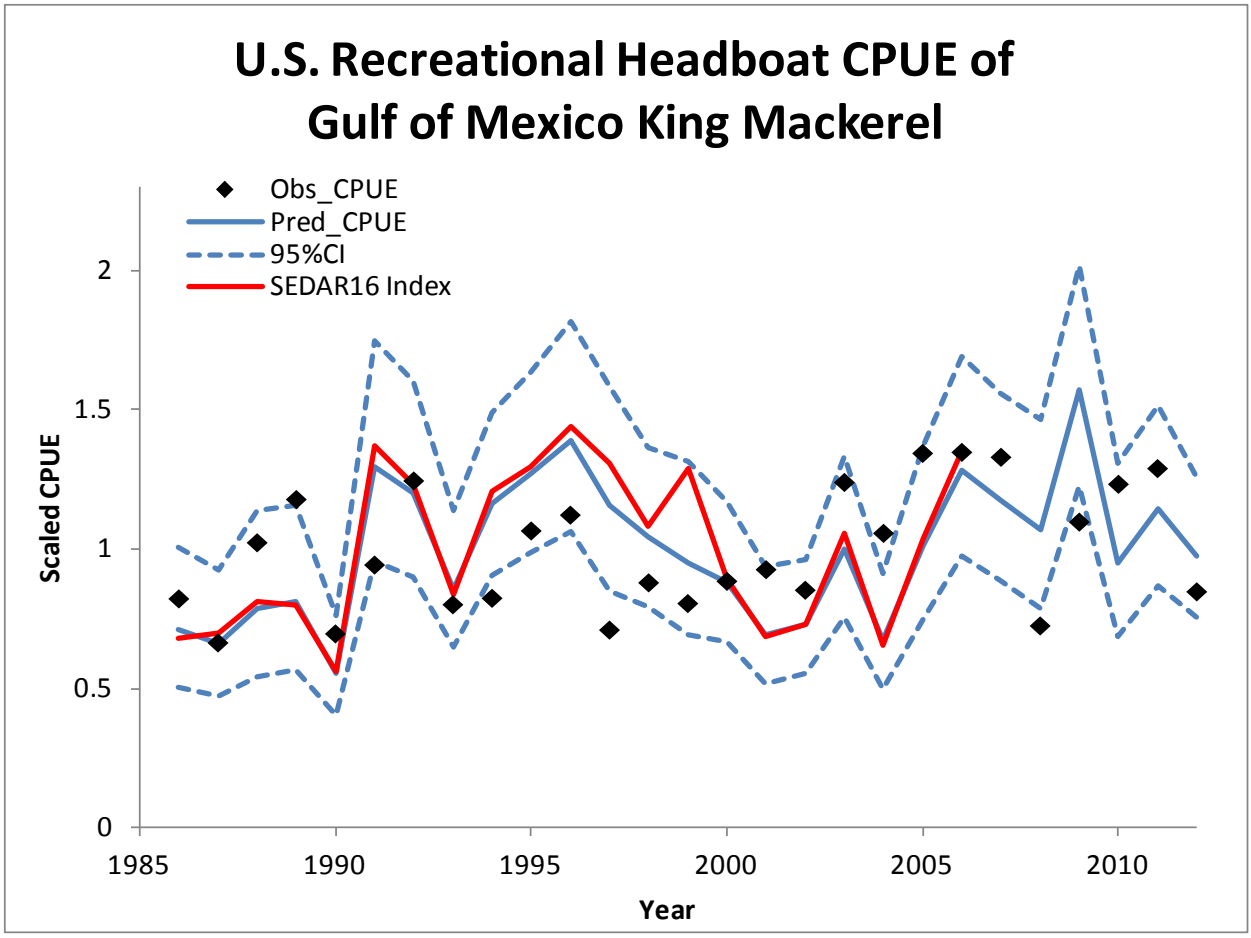

Figure 2. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the Gulf of Mexico (non-mixing).

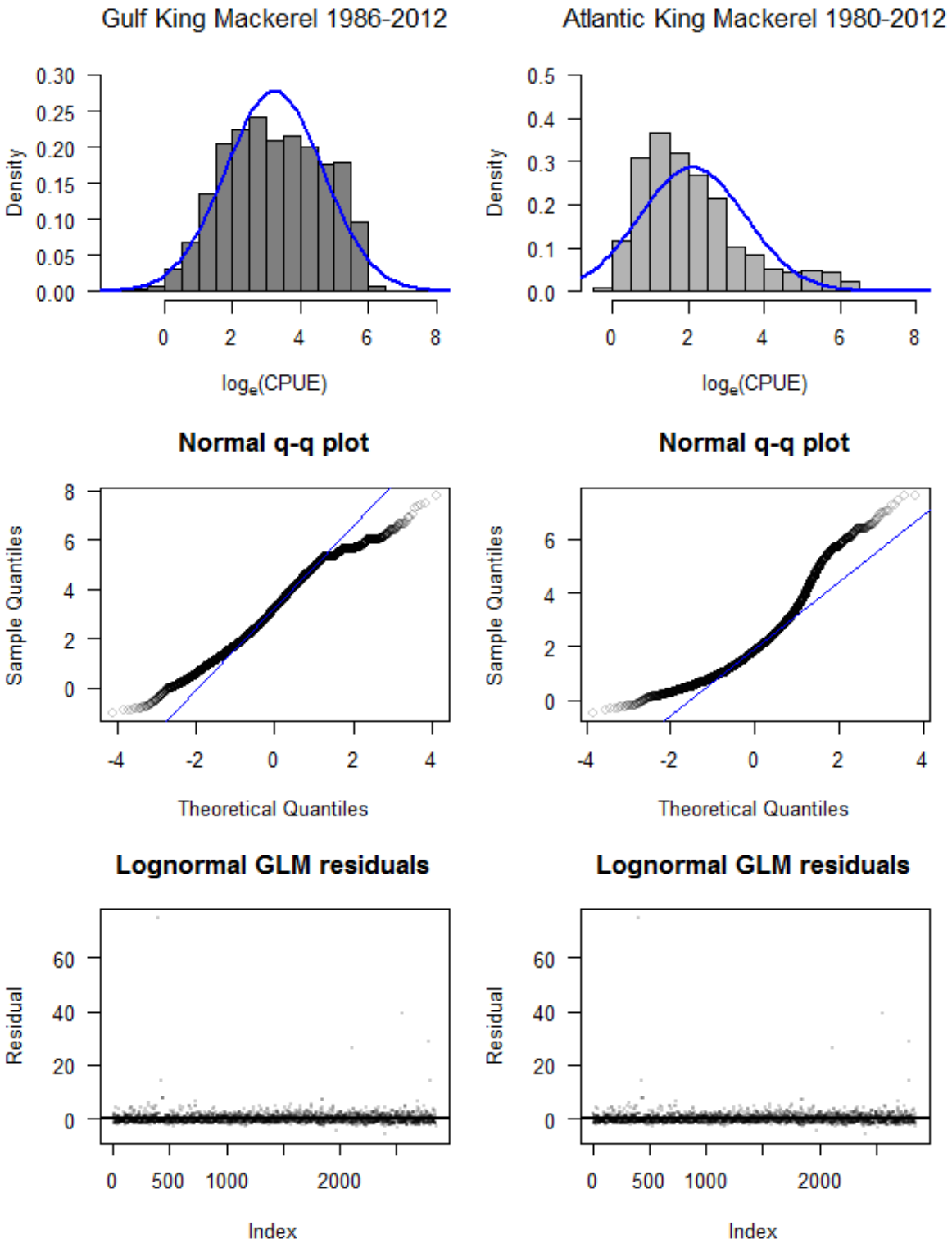

Figure 3. Model diagnostics of the lognormal generalized linear mixed model on positive catch rates of king mackerel caught by the U.S. recreational headboat fisheries.

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SUMMARY

Indices of relative abundance of King mackerel from the United States headboat fishery in the Gulf of Mexico and the U.S. South Atlantic are presented for the period 1980-2012. All were standardized using Generalized Linear Mixed Models, and a delta-lognormal approach. Two updated indices were constructed using the SEDAR 16 methods and area definitions. These are intended to be used during continuity case assessment models. Updated indices were constructed for the U.S. Gulf of Mexico and the U.S. South Atlantic, excluding samples from the winter mixing zone. The analysis used a repeated measures approach on fishing vessels that fished for at least 10 years to account for the variance in catch rates between vessels. Additionally, data were restricted to trips that fished in the habitat of king mackerel, with trip selection based on species composition of co-occurring species.

KEY WORDS

Catch/effort, abundance, headboat, multivariate analyses

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1. INTRODUCTION

Rod and reel catch and effort from party (head) boats have been monitored by the NMFS Southeast Zone Headboat Survey (conducted by the NMFS Beaufort Laboratory) since 1973 in the U.S. South Atlantic and 1986 in the U.S Gulf of Mexico. The Headboat Survey collects data on the catch and effort for a vessel trip. Reported information includes landing date and location, vessel identification, the number of anglers, fishing location, trip duration and/or type (half/three-quarter/full/multi-day, day/night, morning/afternoon), and catch by species in number and weight. These data were used to construct standardized catch rate indices for king mackerel in the U.S. South Atlantic and Gulf of Mexico and as defined by the SEDAR 16 assessment panel.

2. MATERIALS AND METHODS

Two indices, one each for the Atlantic and Gulf of Mexico migratory groups, were constructed using the methods employed during the previous assessment (Cass-Calay 2008). The following factors were previously determined to influence the proportion positive trips, the catch rates on positive trips, or both, and the continuity indices used these same set of factors:

1) ATLANTIC INDEX		
FACTOR	**LEVELS**	**DESCRIPTION**
YEAR	28	1979 – 2006
SEASON	4	Jan – Mar Apr – Jun, Jul –Oct Nov-Dec
AREA	10	1 = Cape Hatteras Offshore
		2 = Cape Fear Inshore
		3 = Cape Fear Offshore
		4 = South Carolina Inshore
		5 = South Carolina Offshore
		6 = Georgia
		7 = NE Florida ***IF LATITUDE ≥ 29°N or Unreported***
		8 = East Central Florida ***IF LATITUDE ≥ 29°N***
		9 = Cape Lookout Inshore
		10 = Cape Lookout Offshore
VESSEL		Analyzed using "Repeated Measures" approach

2) GULF INDEX		
FACTOR	**LEVELS**	**DESCRIPTION**
YEAR	21	1986 – 2006
SEASON	4	Jan – Mar Apr – Jun, Jul –Oct Nov-Dec
AREA	7	21 = Naples/Crystal River ***IF LATITUDE ≥ 26°N or Unreported***
		22 = FL Middle Grounds
		23 = NW Florida and Alabama
		24 = Louisiana
		25 = NE Texas - Sabine/Freeport
		26 = Central Texas - Port Aransas
		27 = South Texas - Port Isabel
VESSEL		Analyzed using "Repeated Measures" approach

The variable "Hours Fished" does not exist in the dataset. To estimate the number of hours fished, the following assumptions were necessary [2].

TRIP CODE	DEFINITION	HOURS FISHED
21,29	½ day, in PM	5
23	¾ day (2nd trip)	7
1,9	½ day, in AM or at night	5
3	¾ day	7
2,4	Full day or Overnight	10
25	1½ days	18
5	Two days	24
6	Three days	26
7	Four days	48
8	Five days	60
10	Six days	72
11	Seven days	84

Catch rate (CPUE) on positive trips was calculated in number of fish per 1000 angler hours.

CPUE = 1000 *{number of fish / (anglers * hours fished)}

Modeling of Vessel Effects

Three regions were considered: 1) the Atlantic, 2) the "Mixing Area" and 3) the Gulf of Mexico. The indices described in this section were constructed using the fishing year. No adjustment was made to accommodate the "fishing year" definitions to be consistent with the Trips prior to 1979 were excluded since they almost never report landing king mackerel. Trips longer than 24 hours *were not* excluded from these analyses.

The variation in catch rates by VESSEL was examined using a "repeated measures" approach (Little et al., 1998). The term "repeated measures" refers to multiple measurements taken over time on the same experimental unit (i.e. vessel). Specifying the repeated measure "VESSEL" and the subject "VESSEL(YEAR)" allows PROC MIXED to model the covariance structure of the data. This is particularly important because catch rates may vary by vessel *and because* catch rates on trips by a given vessel close in time can be more highly correlated that those far apart in time (Littell et al., 1998).

Selection of Trips Using Species Composition

A data filtering technique was used to restrict the dataset to trips that fished in the habitat of king mackerel. In the absence of direct information useful to infer targeting (e.g. depth of fishing, fine-scale fishing location, bottom type, gear configuration), an objective approach developed by Stephens and McCall (2004) was used to subset trip records using species composition. A brief summary of the methodology follows (***adapted from Stephens and McCall, 2004):***

First, the species composition from catch records was used to estimate the parameters of a logistic regression. For example, let Y_j be a categorical variable describing the presence/absence of the non-target species for trip j. Similarly, let x_{ij} describe the presence/absence of king mackerel.

$$Y_j = \begin{cases} 1 & \text{if the target species is caught} \\ 0 & \text{if the target species is not caught} \end{cases}$$

[2] Personal Communication, Bob Dixon, NOAA Headboat Survey Program,

Then a logistic regression was applied to estimate the probability that king mackerel would have been encountered on a trip. Using the regression results, a score (S_j) was assigned to each trip j as a function of the species encountered on that trip:

$$S_j = \exp \sum_{i=0}^{k} x_{ij}\beta_i$$

where the coefficients $\beta_1,\beta_2,\ldots\beta_k$ quantify the predictive effect of each species and β_0 is the intercept of the logistic regression.

This score was then converted into the probability of observing king mackerel given the vector of presence/absence of the other species observed on the trip (j).

$$\pi_j = \Pr\{Y_j = 1\} = \frac{S_j}{1 + S_j}$$

Given the coefficients β_0, β_1, . . ., β_k and the presence/absence indicators $x_{1j},\ldots, x_{kj}$, the log-likelihood (excluding constants independent of the parameters) is the sum:

$$L\{Y|\beta_0, \ldots, \beta_k, x_{1j}, \ldots, x_{kj}\} = \sum_{j \in j+} \log(\pi_j) + \sum_{j \in j-} \log(1 - \pi_j)$$

where j+ indicates trips that observed king mackerel, and j- indicates trips that did not observe king mackerel. The log-likelihood was maximized using the statistical package R (Ihaka and Gentleman, 1996). The estimated β coefficients reflect the association (positive or negative) between the non-target species and king mackerel, π_j is intended to estimate the probability that the trip *j* fished in the habitat of king mackerel.

Trip records were selected for CPUE analysis using a critical value. The critical value was determined by examining the relationship between the critical value and the number of incorrect predictions. Both false positives (king mackerel predicted to occur when absent) and false negatives (king mackerel not expected to occur when present) were considered. The critical value that minimized the number of incorrect predictions was selected. Trip records were included in the CPUE analysis if π (as calculated above) was above the critical value.

Recreational Fishery Regulations

King mackerel recreational landings are managed using three types of fishing regulations, minimum size limits, bag limits and fishing closures. These vary by year and management region (ATL, GOM), and are summarized in **Table 1**. Analyses undertaken to examine the effects of management regulations on fisheries dependent indicators, including the HB indices, are described in SEDAR16-AW-02.

A) Bag Limits: Although various bag limits have been mandated during the time series (**Table 1**), it was determined during SEDAR 16 that no significant effect of the bag limit was found for the Atlantic or headboat fisheries. This result agrees with the testimony of headboat captains present at the SEDAR16 DW. They reported that catches of king mackerel (on headboat trips) were not often restricted by the bag limit since the individual bag limit is multiplied by the large number of anglers on board. The continuity indices were constructed under this same assumption.

B) Size Limits: The SEDAR 16 working group recommended that changes in selectivity caused by increasing the minimum size limit be estimated by the SS3 model directly. Therefore, they did not recommend breaking the indices at the changes in size limit. Previous king mackerel

assessments did not break the indices at the changes in size limit. Therefore, the continuity indices were constructed as unbroken time-series.

C) Fishing Closures: Several fishing closures were enacted during the time-series (**Table 1.**) According to regulation §622.43 paragraph (a)(3)(ii), a person aboard a vessel for which valid charter vessel/headboat permits for Gulf coastal migratory pelagic fish or South Atlantic coastal migratory pelagic fish and a valid commercial vessel permit for king or Spanish mackerel have been issued may continue to retain fish under a bag and possession limit specified in § 622.39(c), provided the vessel is operating as a charter vessel or headboat. However, sale of the closed species is prohibited. No data was presented to the SEDAR16 DW to determine which headboat vessels also possessed a commercial permit during the time-series, nor is it clear whether these boats fish in the same manner during open and closed seasons. For these reasons, all trips that occurred during recreational fishing closures were excluded from the analyses.

3. RESULTS AND DISCUSSION

Table 2 and **Table 3** list the model factors determined to be significant during SEDAR 16, and these same set of factors were used to generate the SEDAR 38 continuity indices. Continuity indices demonstrated similar fit to the observed catch rate data as the previous assessment base indices, indicating the model structure and assumptions used in SEDAR 16 were effectively reproduced (**Figures 1 and 2**). Catch indices of King mackerel in the Atlantic Ocean indicated a decline since 2009, with the standardized index for 2012 predicted to be the lowest of the time series (**Table 4, Figure 1**). Catch indices of King mackerel in the Gulf of Mexico indicated a more stable trend over the last decade (**Table 5, Figure 2**), with recent indices near or greater than the mean observed across the time series. Model fit diagnostics indicated a moderately good fit of the normal probability distribution to the observed data near the distribution center for both groups, but also showed a lack-of-fit to the upper and lower quantiles of the data (**Figure 3**), particularly for the Atlantic group. Model residuals were approximately normal, with the exception of few outliers in which the model demonstrated a strong negative bias in predictions (**Figure 3**), although these outliers represented a few data points. Kilmogorov-Smirnov goodness-of-fit tests (KS test) on the data quantiles (0 quantile to the 100^{th} quantile, by increments of one percent) indicated that the distribution of the log-transformed positive catch rate data were not significantly different from a normal probability model in both the Atlantic (KS test p-value >0.9) and the Gulf of Mexico (KS test p-value = 0.7).

4. REFERENCES

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Table 1. King Mackerel recreational fishing regulations.

	Fishing Year			Bag Limit		Closures	
Year	Atlantic	Gulf	Size Limit	Atlantic	Gulf	Atlantic	Gulf
1983-1984[1]			--	--	--	--	--
1984-1985[1]			--	--	--	--	--
1985-1986[2]	4/1 - 3/31	7/1 - 6/30	--	--	--	--	--
1986-1987	4/1 - 3/31	7/1 - 6/30	--	Private = 2/person/trip; Charterboat = greater of 2/person incl capt&crew or 3/person excl capt&crew		--	--
1987-1988	4/1 - 3/31	7/1 - 6/30	--	3/person/trip	"		Closed 12/16/87 0100h Reopened 7/1/1988 0001h
1988-1989	4/1 - 3/31	7/1 - 6/30	--	2/person/trip FL & 3 GA to NC	"	Closed 10/17/88 0100h Reopened 4/1/89 0001h	Closed 12/17/88 0001h Reopened 7/1/1989 0001h
1989-1990	4/1 - 3/31	7/1 - 6/30	--	2/person/trip FL & 3 GA to NC	"		
1990-1991[3]	4/1 - 3/31	7/1 - 6/30	12 in FL or 14 in TL	2 FL; 3 GA-NY	Same as above[4]		Closed 12/20/90 0001h Reopened 7/1/1991 0001h
1991-1992	4/1 - 3/31	7/1 - 6/30	12 in FL or 14 in TL	5 FL-NY	"		Closed 01/13/92 Reopened 7/1/1992
1992-1993	4/1 - 3/31	7/1 - 6/30	20 in FL	2 FL; 5 GA-NY	2 per person including captain & crew		--
1993	Calendar Year		20 in FL	"	"		--
1994	Calendar Year		20 in FL	"	"		--
1995	Calendar Year		20 in FL	2 FL; 3 GA-NY	"		--
1996	Calendar Year		20 in FL	"	"		--
1997	Calendar Year		20 in FL	"	2 per person, 0 capt&crew as of 6-97		--
1998	Calendar Year		20 in FL	"	2 per person, 2 capt&crew as of 2-98		--

Table 1 Cont. King Mackerel recreational fishing regulations.

1999	Calendar Year	24 in FL	"	2 per person, 0 capt&crew as of 9-99	--
2000-2012	Calendar Year	24 in FL	"	2 per person, 2 capt&crew as of 6-00	--

[1]One stock

[2]Two management groups (Atlantic & Gulf migratory) from this point forward

[3]Management area expands from TX through NC to TX through NY

[4]Redefined as daily bag limits; 1-day possession except for-hire on multi-day can have 2-day possession

Table 2. SEDAR 16 analysis of the mixed model formulations of King mackerel indices with Species Composition –Atlantic Region. The selected models are indicated with gray shading and were used in the SEDAR 38 continuity update.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Area+ Year + Season	**67957.8**	**67959.8**	**67967.5**	**-**	**-**
Area+ Year + Season + Year*Area			Did not converge		
Area+ Year + Season + Year*Season			Did not converge		

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Area + Year + Season + Area*Season	22453.8	22455.8	22462.7	-	-
Area + Year + Season + Area*Season + Year*Area	22282.6	22286.6	22292.9	171.2	<0.0001
Area + Year + Season + Area*Season + Year*Area + Year*Season	22262.5	22268.5	22277.9	20.1	<0.0001
Area + Year + Season + Area*Season + Vessel(Year)	19212.9	19216.9	19225.6	3240.9	<0.0001
Area + Year + Season + Area*Season + Vessel(Year) + Year*Area			Did not converge		
Area + Year + Season + Area*Season + Vessel(Year) + Year*Season	**19174.4**	**19180.4**	**19188.2**	**38.5**	**<0.0001**

Table 3 . Analysis of the mixed model formulations of the SEDAR 16 Indices with Species Composition – Gulf Region. The final selected models are indicated with gray shading and were used for the SEDAR 38 continuity update.

ANALYSIS OF MIXED MODEL FORMULATIONS

Proportion Positive	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Season + Area + Year	**9127.5**	**9129.5**	**9135.2**	**-**	**-**
Season + Area + Year + Year*Season	9351.5	9355.5	9360.4	-224.0	1.0000
Season + Area + Year + Year*Area	9128.3	9132.3	9138.1	-0.8	1.0000

Catch Rates on Positive Trips	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	P
Area + Season + Year	63142.0	63144.0	63151.8	-	-
Area + Season + Year + Year*Area	62562.2	62566.2	62571.8	579.8	<0.0001
Area + Season + Year + Year*Area + Year*Season	62434.6	62440.6	62449.1	127.6	<0.0001
Area + Season + Year + Vessel(Year)	59569.7	59573.7	59582.9	3572.3	<0.0001
Area + Season + Year + Vessel(Year) + Year*Area			Not Convergent		
Area + Season + Year + Vessel(Year) + Year*Season	**59374.2**	**59380.2**	**59387.3**	**3060.4**	**<0.0001**

Table 4. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the U.S. South Atlantic Ocean (non-mixing).

Year	n	Obs_CPUE	Obs_Prop_Pos	Standardized_CPUE	95%_CI_LL	95%_CI_UL	CV
1980	132	7.02	0.37	0.60	0.25	1.40	0.45
1981	101	8.21	0.34	1.45	0.56	3.76	0.50
1982	168	3.53	0.41	0.63	0.23	1.69	0.53
1983	249	4.41	0.55	1.58	0.76	3.30	0.38
1984	292	8.32	0.59	0.91	0.50	1.67	0.31
1985	321	3.34	0.44	0.57	0.31	1.05	0.31
1986	447	4.96	0.42	0.60	0.37	0.98	0.25
1987	615	8.25	0.45	0.81	0.50	1.32	0.25
1988	461	5.35	0.51	0.83	0.50	1.37	0.25
1989	250	2.64	0.41	0.49	0.27	0.88	0.30
1990	359	2.97	0.41	0.65	0.35	1.21	0.31
1991	532	16.01	0.59	1.32	0.80	2.18	0.25
1992	674	13.96	0.63	1.71	1.07	2.75	0.24
1993	758	9.62	0.50	0.76	0.47	1.24	0.25
1994	695	5.83	0.41	0.60	0.36	1.00	0.26
1995	765	5.22	0.42	0.70	0.43	1.13	0.25
1996	655	6.17	0.35	0.48	0.28	0.81	0.27
1997	545	17.91	0.45	1.08	0.66	1.76	0.25
1998	754	30.76	0.54	1.36	0.87	2.14	0.23
1999	684	10.10	0.47	1.04	0.65	1.66	0.24
2000	835	35.88	0.61	1.91	1.23	2.97	0.22
2001	642	21.03	0.52	1.43	0.90	2.28	0.23
2002	608	16.16	0.48	0.91	0.55	1.52	0.26
2003	456	27.19	0.51	0.98	0.60	1.59	0.25
2004	619	27.94	0.39	1.03	0.63	1.67	0.25
2005	459	21.42	0.53	1.34	0.79	2.28	0.27
2006	584	29.33	0.53	1.25	0.79	2.00	0.24
2007	676	22.73	0.59	1.49	0.94	2.37	0.23
2008	472	21.79	0.44	1.20	0.75	1.92	0.24
2009	581	22.07	0.47	1.27	0.79	2.05	0.24
2010	500	15.36	0.38	0.87	0.50	1.49	0.28
2011	418	21.55	0.39	0.70	0.40	1.21	0.28
2012	378	7.31	0.34	0.44	0.24	0.80	0.30

Table 5. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the Gulf of Mexico (non-mixing).

Year	n	Obs_Prop_Pos	Obs_CPUE	Standardized_CPUE	95%_CI_LL	95%_CI_UL	CV
1986	966	0.52	29.60	0.71	0.50	1.00	0.17
1987	1098	0.49	23.92	0.66	0.48	0.92	0.17
1988	701	0.57	36.83	0.79	0.54	1.14	0.19
1989	801	0.59	42.41	0.81	0.57	1.16	0.18
1990	1471	0.42	25.09	0.55	0.40	0.76	0.16
1991	860	0.64	33.96	1.29	0.96	1.75	0.15
1992	1167	0.63	44.80	1.20	0.90	1.60	0.15
1993	1599	0.49	28.84	0.86	0.65	1.14	0.14
1994	2038	0.58	29.67	1.16	0.90	1.49	0.13
1995	2064	0.62	38.36	1.27	0.99	1.64	0.13
1996	1676	0.63	40.39	1.39	1.06	1.81	0.13
1997	1109	0.55	25.58	1.16	0.85	1.58	0.16
1998	1875	0.57	31.67	1.04	0.79	1.37	0.14
1999	1074	0.47	29.00	0.95	0.69	1.31	0.16
2000	1776	0.55	31.86	0.88	0.66	1.17	0.14
2001	1643	0.53	33.37	0.69	0.52	0.93	0.15
2002	1978	0.53	30.71	0.73	0.55	0.96	0.14
2003	1647	0.61	44.61	1.00	0.75	1.33	0.14
2004	1559	0.55	38.05	0.67	0.50	0.91	0.15
2005	1495	0.59	48.35	1.01	0.75	1.37	0.15
2006	1851	0.67	48.49	1.28	0.97	1.69	0.14
2007	1550	0.63	47.85	1.18	0.89	1.56	0.14
2008	854	0.50	26.11	1.07	0.78	1.46	0.16
2009	1871	0.65	39.50	1.57	1.22	2.02	0.13
2010	1240	0.59	44.37	0.95	0.69	1.31	0.16
2011	1394	0.64	46.40	1.15	0.87	1.51	0.14
2012	1958	0.63	30.51	0.97	0.75	1.26	0.13

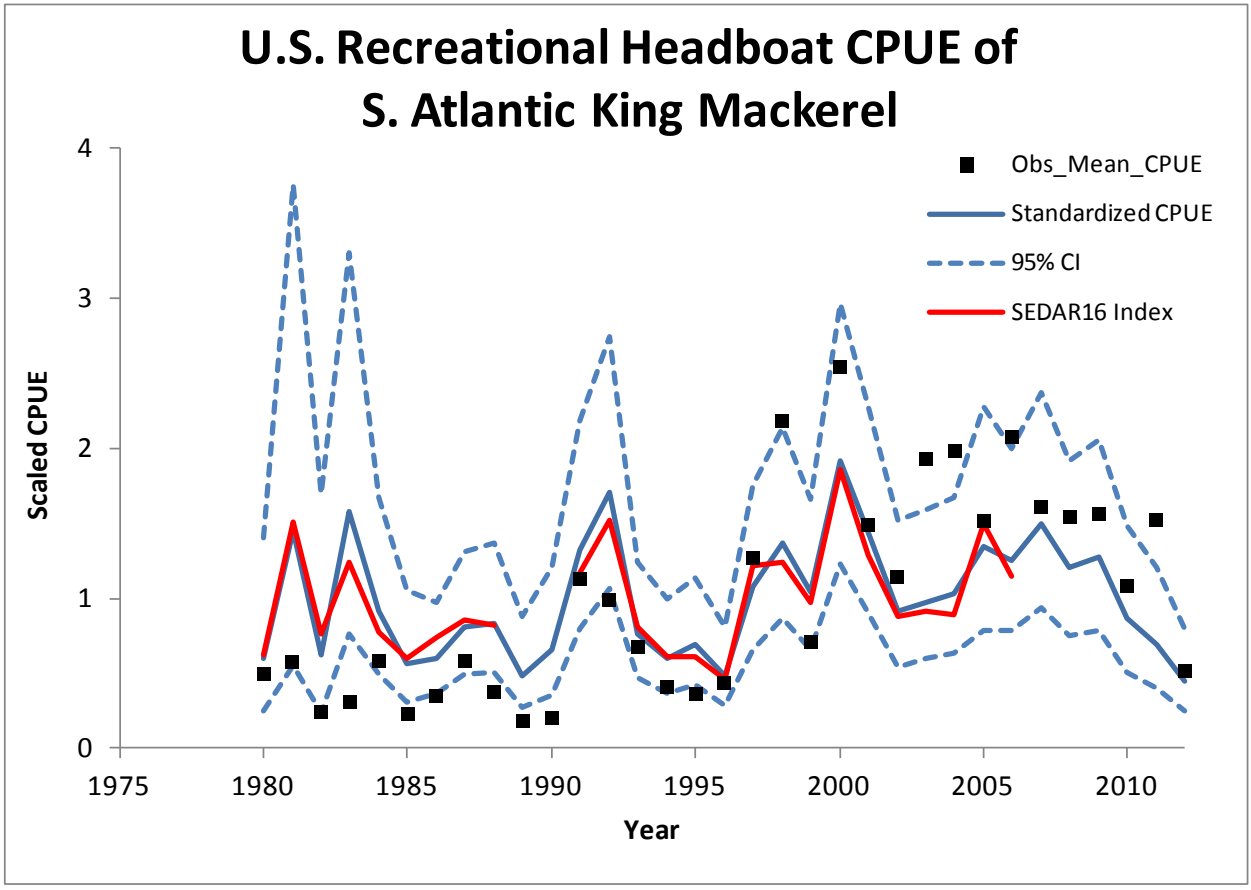

Figure 1. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the South Atlantic (non-mixing).

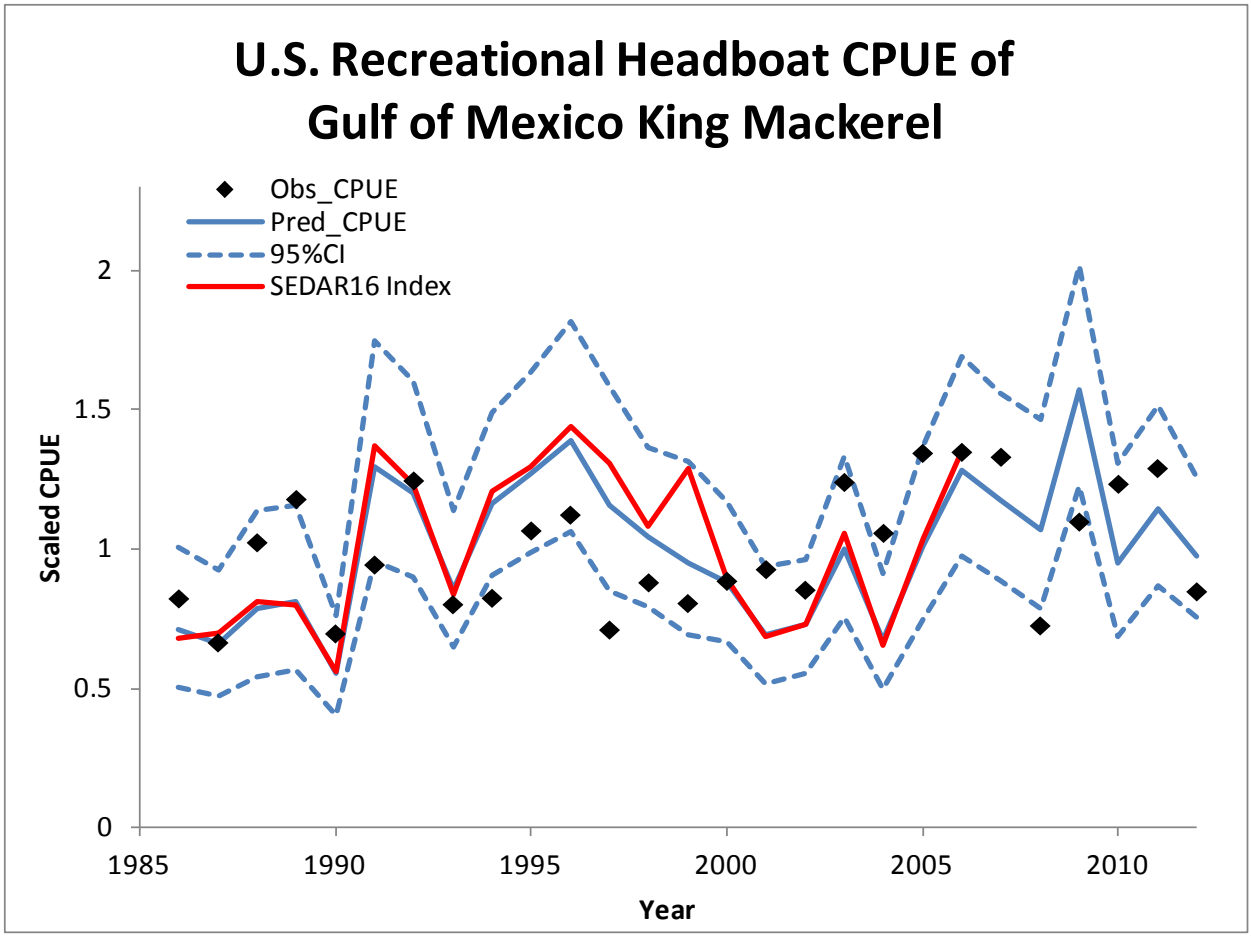

Figure 2. Updated catch indices of king mackerel from the U.S. recreational headboat fishery in the Gulf of Mexico (non-mixing).

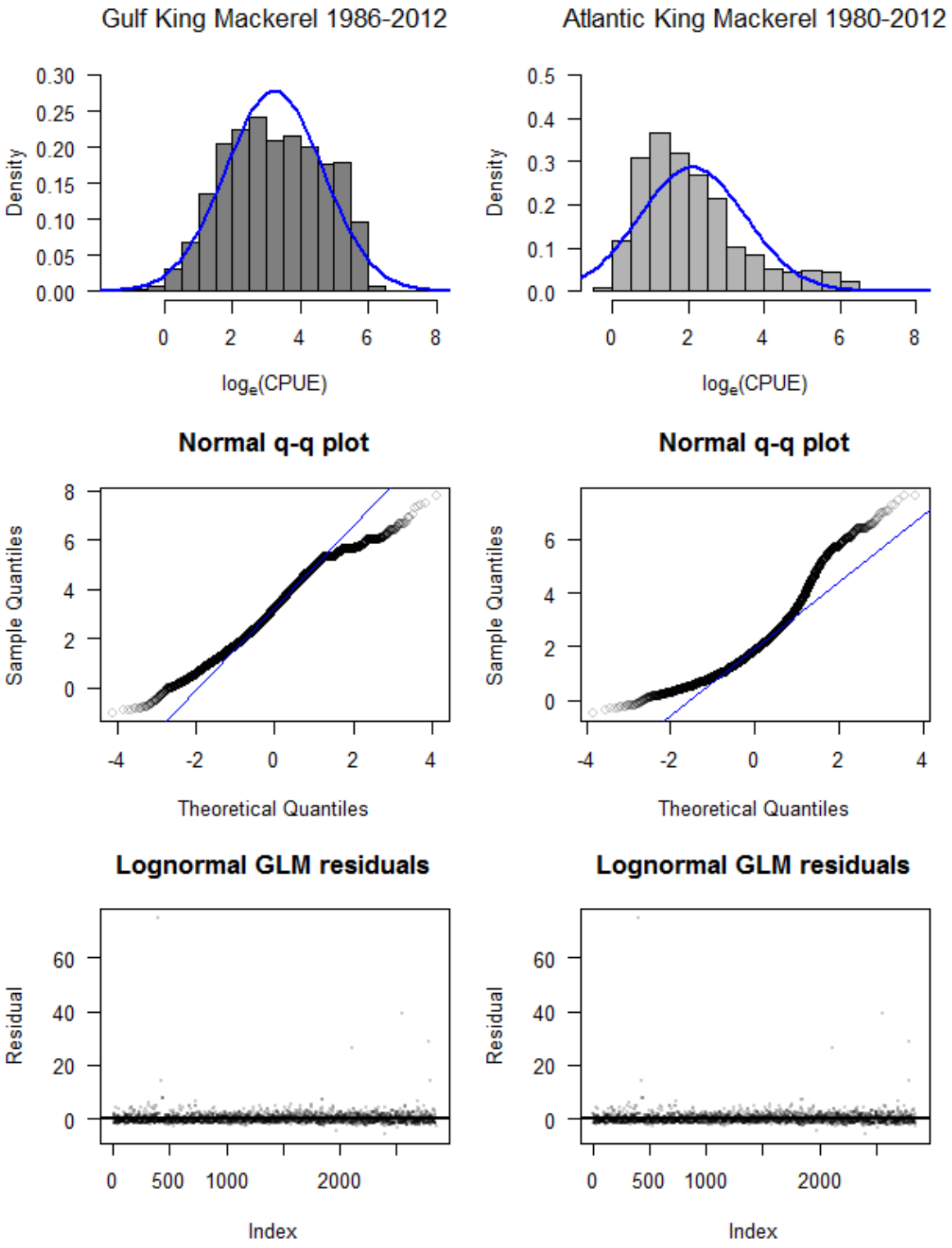

Figure 3. Model diagnostics of the lognormal generalized linear mixed model on positive catch rates of king mackerel caught by the U.S. recreational headboat fisheries.