Standardized catch rates of king mackerel, *Scomberomorus cavalla* from the Marine Recreational Fisheries Statistical Survey MRFSS.

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SUMMARY

Catch and effort data from the US Marine Recreational Fisheries Statistical Survey of the Atlantic coast and Gulf of Mexico (excluding Texas) were used to update the indices of abundance for king mackerel Gulf of Mexico and Atlantic stocks. Standardized catch rates were estimated using a Generalized Linear Mixed modeling approach assuming a delta-lognormal error distribution. The explanatory variables considered for standardization included: geographical area, seasonal trimesters, fishing target species, and mode (a factor that classifies recreational fishing in shore, charter or private/rental boat).

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Introduction

Indices of abundance from recreational fisheries have been used to tune stock assessment models (Quinn and Deriso 1999). Data collected and estimated by the Marine Recreational Fisheries Statistical Survey (MRFSS) were used to develop standardized catch per unit effort (CPUE) indices for the king mackerel stocks of the Gulf of Mexico and Atlantic. The recreational fisheries survey started in 1979, and its purpose is to establish a reliable database for estimating the impact of marine recreational fishing on marine resources. More detailed information on the methods and protocols of the survey can be found at http://www.st.nmfs.gov/st1/recreational/overview/ overview.html. This Report updates the methods applied to the available US recreational data through 2007, and presents the king mackerel standardized indices for Gulf or Mexico (GOM) and Atlantic (ATL) stocks. Standardized catch rates were estimated using the Generalized Linear Mixed Model (GLMM) approach.

Materials and methods:

The MRFSS estimates of catch and effort were based on intercept (i.e. interview at dock) and telephone surveys. Each record report included: the catch in numbers of all caught species; whether it was retained, or released alive or death; number of participating anglers; number of fishing hours; information on gear used; target species; mode (shore, headboat, charter, or private/rental); area (inshore, ocean < 3 miles, 3 < ocean < 10 miles, ocean > 10 miles); county/state; and date. Headboat mode trip/interviews were not included in any of the present analyses. The frequency and sampling design of the interview and telephone surveys were based on demographic and seasonal (wave) considerations by county from Maine through Louisiana on the Atlantic and US Gulf of Mexico coast. This Report does not include MRFSS estimates from the US Caribbean region.

The MRFSS data included the estimates of catch and effort from 1981 through 2007 from Louisiana through Maine. Because of the reduced number of records for some states, regional areas were defined and used as a spatial factor: Central Gulf (LA, AL, MS), Western Gulf (FLW), Florida east coast (FLE), NC-GE (GE, SC, NC), Mid Atlantic (VA, MD, DE, NJ, NY), and New England (CT, RI, MA, NH, ME). Trimesters were used to account for seasonal fishery distribution through the year (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec). Interviews also collected information on the intended target species for each trip; based on the ecological and habitat groups, target species were classified into "guilds" in the MRFSS data base: inshore species, reef species, non-reef species, pelagic species, and sharks. When no primary or secondary target was specified, the record was assigned as an unclassified guild. Fishing effort (angler hours) was estimated as the number of anglers times the number of hours fishing; nominal catch rates were defined as the total catch kept and released (AB1B2, number of fish) per thousand angler hours.

Figure 1 shows a summary of the reported recreational catch of king mackerel, other *Scomberomorus* species (Spanish mackerel and Wahoo), and unclassified groupers in general from the MRFSS interview data. Recreational catch of mackerels has been primarily king and Spanish. The total number of fish caught increased, particularly since the early 1990s, for king mackerel; recreational catch has been slightly larger in the Gulf of Mexico in recent years (Fig 1). Since 1981, the recreational fishing effort has increased. By 2006, the total fishing hours were about 0.43 million or 4 times the effort in 1981 (Fig 2), with twice the fishing effort in the Atlantic than the Gulf. However, the percent of effort that reported catches of king mackerel was higher in the Gulf, about 3% than in the Atlantic (1.5%) (Fig 3).

One potential problem with indices derived from the recreational MRFSS database is the selection of trips/interviews that have relevance to the species in the analysis, in this case king mackerel. MRFSS covers all recreational fisheries from shore anglers or small bays up to large charter vessels fishing offshore. The task is then to identify the trips that potentially had a positive probability of catching king. In the interview, anglers are asked for targeted species of each trip, and in general the catch composition reflects the species found in the habitat associated with the intended/target species. As mentioned before, the MRFSS database classified the trips into "guilds" based on habitat related species: sharks, pelagic species, inshore species, reef species, and non reef species. However, about 50% of the trip-interviews did not have a target species definition. Looking in more detail at the trips that caught king mackerel and the other species reported in the same trip, it is possible to create a matrix of co-occurring species, and possibly use this composition matrix

as a subsetting condition. From 1981 to 2006, 14,775 trip/interviews reported catches of king in the Gulf of Mexico, and 14,997 trip/interviews reported catches of king in the Atlantic. In the Gulf, the most common co-occurring species was red snapper (21%), followed by little tunny and Spanish mackerel (Fig 4). In general, the reef-associated and pelagic species were the main co-occurring species (98%). In the Atlantic, the most common co-ocurring species was little tunny (19%), followed by dolphin fish, Spanish mackerel and great barracuda (Fig 4).

Stephens and MacCall (2004) developed a multispecies approach to sub-setting trips of catch and effort data based on the species composition of each trip. Using a logistic regression, they predict a probability that the species of concern, in this case king mackerel, would be present in a given trip. Then, a minimum probability threshold is defined, which is used to select a given subset of trips/records. This approach was attempted for the Atlantic and Gulf MRFSS catch, however the logistic regression did not converge to a solution for any of the king stocks. Standardization analyses were done with trips/records of guild pelagic species, reef species and unclassified guild species.

Standardized indices of abundance were estimated for the king mackerel Gulf of Mexico and Atlantic current stock unit definition (the Gulf stock boundary extends into the Florida east coast up to Volusia-Flagler County line during the Nov-Mar months, while during the Apr-Oct months the Collier-Monroe county line is the boundary), as well as by regions, where the Atlantic no mix region is north of Flagler county, the Gulf no mix region is north and west of Collier county, and the mix region is the Florida east coast between Monroe and Volusia counties. King relative indices of abundance were estimated by the Generalized Linear Modeling approach assuming a delta lognormal model distribution. The standardization protocols assumed a delta model with a binomial error distribution for modeling the proportion of positive sets, and a lognormal error distribution for modeling the mean catch rate of successful (i.e. positive king catch) trip/interviews. The nominal log transformed the king catch rate distributions of all positive trip/interview records from the MRFSS data are shown in Figure 5. Parameterization of the models used the GLM structure; the proportion of successful observations per stratum was assumed to follow a binomial distribution where the estimated probability was a linear function of fixed factors and interactions. The logit function was used as a link between the linear factor component and the binomial error. For successful trip/interviews, estimated CPUE rates assumed a lognormal distribution of a linear function of fixed and random effect interactions 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. As the difference in the deviance between two consecutive nested models follows a chi-square (χ^2) distribution, this statistic was used to test for the significance of an additional factor(s) in the model. Deviance tables are presented for each analysis. Each table includes the deviance for the proportion of positive observations, and the deviance for the positive catch rates. Final selection of the explanatory factors was conditional on: a) the relative percent of deviance explained by adding the factor in consideration (normally factors that explained more than 5% were included in the final model), b) the χ^2 test significance, and c) a type III test significance within the final specified model. Once a set of fixed factors was specified, possible first level interactions were evaluated and in particular interactions between the *year* effect and other factors which were assumed to be random. The significance of random interactions was evaluated between nested models by using the likelihood ratio test (Pinheiro and Bates 2000), the Akaike information criteria (AIC), and the Bayesian information criteria (BIC) (Littell et al 1996), where lower values indicated better model fitting. Analyses were done using GLIMMIX and MIXED procedures from the SAS® statistical computer software (SAS Institute Inc. 1997)

Relative indices were calculated as the product of the year effect least square means (LSmeans) from the binomial and the lognormal components. LSmeans estimates were weighted proportional to observed marginal sums in the positive observations data; for the lognormal estimates, a log-back transformed bias corrections was applied (Lo et al. 1992). Final model for the region scenarios were used to estimate year-season indices requested for assessment models that track seasonal changes of abundance.

Results

The deviance analyses tables for all records of the Atlantic king CPUE standardization from the MRFSS data are shown in Table 1. Table 3 shows the deviance table for the Gulf of Mexico king from the MRFSS data. The step wise analyses of

deviance indicated that guild, area and region were the main explanatory factors for the proportion of positive trips model in both the Atlantic and Gulf stocks. For the positive catch trips model, the main explanatory factors were mode, area, guild, season and region in the Atlantic and the Gulf stocks. Of the interactions evaluated, the year*region was the most important explanatory factor for the proportion positive model for the Atlantic stock, while year*season, year*mode and year*region were significant interactions in the positive catch rate model. In contrast, for the Gulf stock year*season, year*region, year*mode and year*area were significant interactions in the positive catch model. Tables 2 and 4 present the evaluation of these interactions as random components in the mixed models.

Similar tables of deviance and random effects evaluation are shown for the analyses of catch rates by regions, Atlantic no mix zone (Tables 5 and 6), Gulf no mix zone (Table 7 and 8), and the mixing zone (Table 9 and 10). Tables 11 and 12 show the nominal and standardized CPUE for Atlantic and Gulf king current stock definition from the MRFSS data, noted that the year in each stock correspond to the fishing year; April through March for Atlantic king, and Jul through June for Gulf king. Tables 13, 14 and 15 show nominal and standardized CPUE series by region for calendar years. Finally, tables 16, 17 and 18 show the estimated CPUE series by year and season, using the final model in each scenario. Reviewing index trends for Atlantic king, they showed no trend of catch rates with a high value in FY 1987, with broad estimated 95% confidence intervals and a CV (coefficient of variation) averaging 42% for the Atlantic index. In the Gulf, the relative index showed an increasing trend, with values below the overall mean prior to 1990, and over the mean from 1990 to 1995, and decreased in recent years, except in 2006. Estimated 95% confidence intervals were narrower compared to the Atlantic stock, and averaged 30% overall.

References

LITTELL, R.C., G.A. Milliken, W.W. Stroup, and R.D Wolfinger. 1996. SAS® System for Mixed Models, Cary NC:SAS Institute Inc., 1996. 663 pp.

LO, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-2526.

PINHEIRO, J.C. and D.M. Bates. 2000. Mixed-effect models in S and S-plus. Statistics and Computing. Springer-Verlag New York, Inc.

Quinn, T.J. and R.B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press. New York.

SAS Institute Inc. 1997, SAS/STAT® Software: Changes and Enhancements through Release 6.12. Cary, NC:Sas Institute Inc., 1997. 1167 pp.

Stephens, A. and A. MacCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fish. Res. 70:299-310.

Table 1. Deviance analysis table of explanatory variables in the delta lognormal model for Atlantic king catch rates (number of fish per thousand angler hours) from the MRFFS data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the Chi-square probability between consecutive models (alpha = 0.05).

King ATLANTIC MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	10194.49			
Year	25	10034.31	160.2	15.4%	< 0.001
Year Area	2	9902.31	132.0	12.7%	< 0.001
Year Area Season	3	9611.75	290.6	28.0%	< 0.001
Year Area Season Mode	1	9519.44	92.3	8.9%	< 0.001
Year Area Season Mode Region	1	9461.44	58.0	5.6%	< 0.001
Year Area Season Mode Region Guild	2	9315.35	146.1	14.1%	< 0.001
Year Area Season Mode Region Guild Area*Region	2	9314.34	1.0	0.1%	0.603
Year Area Season Mode Region Guild Area*Mode	2	9308.64	6.7	0.6%	0.035
Year Area Season Mode Region Guild Area*Guild	4	9303.40	12.0	1.2%	0.018
Year Area Season Mode Region Guild Mode*Region	1	9300.86	14.5	1.4%	< 0.001
Year Area Season Mode Region Guild Season*Guild	6	9297.79	17.6	1.7%	0.007
Year Area Season Mode Region Guild Mode*Guild	2	9290.86	24.5	2.4%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	9290.65	24.7	2.4%	< 0.001
Year Area Season Mode Region Guild Season*Mode	3	9283.82	31.5	3.0%	< 0.001
Year Area Season Mode Region Guild Region*Guild	2	9271.21	44.1	4.3%	< 0.001
Year Area Season Mode Region Guild Year*Area	49	9257.55	57.8	5.6%	0.182
Year Area Season Mode Region Guild Year*Guild	48	9238.95	76.4	7.4%	0.006
Year Area Season Mode Region Guild Year*Region	25	9237.58	77.8	7.5%	< 0.001
Year Area Season Mode Region Guild Year*Mode	25	9234.57	80.8	7.8%	< 0.001
Year Area Season Mode Region Guild Year*Season	73	9157.34	158.0	15.2%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	21063.2115			
Year	25	20486.1942	577.0	4.3%	< 0.001
Year Area	2	11023.4314	9462.8	70.0%	< 0.001
Year Area Season	3	10675.654	347.8	2.6%	< 0.001
Year Area Season Mode	1	10639.7843	35.9	0.3%	< 0.001
Year Area Season Mode Region	1	9401.10368	1238.7	9.2%	< 0.001
Year Area Season Mode Region Guild	2	8626.48187	774.6	5.7%	< 0.001
Year Area Season Mode Region Guild Year*Mode	25	8512.47838	114.0	0.8%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	8457.22611	169.3	1.3%	< 0.001
Year Area Season Mode Region Guild Year*Guild	50	8429.27357	197.2	1.5%	< 0.001
Year Area Season Mode Region Guild Year*Area	50	8240.34599	386.1	2.9%	< 0.001
Year Area Season Mode Region Guild Area*Mode	2	8169.58676	456.9	3.4%	< 0.001
Year Area Season Mode Region Guild Year*Season	74	8112.32385	514.2	3.8%	< 0.001
Year Area Season Mode Region Guild Year*Region	25	7535.32445	1091.2	8.1%	< 0.001

Table 2. Analyses of mixed model formulations for Atlantic king catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models.

King mackerel Atlantic	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Region Guild	14930.2	14932.2	14938.1		
Year Area Region Guild *Year*Region*	14867.1	14871.1	14875	63.1	0.0000
Year Area Region Guild *Year*Region Year*Season*	14752.9	14758.9	14764.8	114.2	0.0000
Positive Catch					
Year Area Season Mode Region Guild	33945.8	33947.8	33955.3		
Year Area Season Mode Region Guild *Year*Season*	33869.9	33873.9	33879.2	75.9	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode*	33813	33819	33826.9	56.9	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region*	33769.5	33777.5	33788	43.5	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region Year*guild*	33741	33751	33764.1	28.5	0.0000

Table 3. Deviance analysis table of explanatory variables in the delta lognormal model for Gulf king catch rates (number of fish per thousand angler hours) from the MRFFS data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the Chi-square probability between consecutive models (alpha = 0.05).

Gulf of Mexico King MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	14085.78			
Year	25	13952.79	133.0	6.9%	< 0.001
Year Area	2	13384.28	568.5	29.4%	< 0.001
Year Area Season	3	13143.57	240.7	12.4%	< 0.001
Year Area Season Mode	2	12985.87	157.7	8.2%	< 0.001
Year Area Season Mode Region	3	12882.42	103.5	5.3%	< 0.001
Year Area Season Mode Region Guild	4	12365.07	517.4	26.7%	< 0.001
Year Area Season Mode Region Guild Season*Mode	6	12331.84	33.2	1.7%	< 0.001
Year Area Season Mode Region Guild Mode*Guild	8	12307.07	58.0	3.0%	< 0.001
Year Area Season Mode Region Guild Area*Guild	8	12298.90	66.2	3.4%	< 0.001
Year Area Season Mode Region Guild Region*Guild	12	12290.96	74.1	3.8%	< 0.001
Year Area Season Mode Region Guild Year*Mode	49	12289.83	75.2	3.9%	0.009
Year Area Season Mode Region Guild Area*Region	6	12268.34	96.7	5.0%	< 0.001
Year Area Season Mode Region Guild Season*Guild	12	12255.50	109.6	5.7%	< 0.001
Year Area Season Mode Region Guild Year*Guild	88	12250.14	114.9	5.9%	0.029
Year Area Season Mode Region Guild Mode*Region	6	12228.29	136.8	7.1%	< 0.001
Year Area Season Mode Region Guild Year*Area	46	12221.49	143.6	7.4%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	12206.52	158.5	8.2%	< 0.001
Year Area Season Mode Region Guild Area*Mode	3	12201.38	163.7	8.5%	< 0.001
Year Area Season Mode Region Guild Year*Region	75	12155.77	209.3	10.8%	< 0.001
Year Area Season Mode Region Guild Year*Season	74	12151.57	213.5	11.0%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	47024.3496			
Year	25	45674.7362	1349.6	4.0%	< 0.001
Year Area	2	27696.7996	17977.9	53.5%	< 0.001
Year Area Season	3	27328.9358	367.9	1.1%	< 0.001
Year Area Season Mode	2	21644.2439	5684.7	16.9%	< 0.001
Year Area Season Mode Region	3	20511.9691	1132.3	3.4%	< 0.001
Year Area Season Mode Region Guild	4	14471.5342	6040.4	18.0%	< 0.001
Year Area Season Mode Region Guild Year*Mode	50	14143.1965	328.3	1.0%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	14089.0177	382.5	1.1%	< 0.001
Year Area Season Mode Region Guild Year*Area	50	14078.6206	392.9	1.2%	< 0.001
Year Area Season Mode Region Guild Year*Guild	100	13959.0591	512.5	1.5%	< 0.001
Year Area Season Mode Region Guild Year*Region	75	13878.2291	593.3	1.8%	< 0.001
Year Area Season Mode Region Guild Year*Season	74	13740.0423	731.5	2.2%	< 0.001
Year Area Season Mode Region Guild Area*Mode	3	13395.0681	1076.5	3.2%	< 0.001

Table 4. Analyses of mixed model formulations for Gulf king catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models.

Gulf of Mexico king mackerel	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Mode Guild Region	68302.3	68304.3	68311.5		
Year Area Mode Guild Region *Year*season*	67948.5	67952.5	67957.8	353.8	0.0000
Positive Catch					
Year Area Season Mode Region Guild	39108.3	39110.3	39117.9		
Year Area Season Mode Region Guild *Year*Season*	39031.7	39035.7	39040.9	76.6	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode*	39014.6	39020.6	39028.5	17.1	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region*	38969.4	38977.4	38988	45.2	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region Year*Guild*	38964.4	38974.4	38987.6	5	0.0253
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region Year*Guild Year*area*	38912.6	38924.6	38940.4	51.8	0.0000

Table 5. Deviance analysis table of explanatory variables in the delta lognormal model for Atlantic no mix zone king catch rates (number of fish per thousand angler hours) from the MRFFS data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the Chi-square probability between consecutive models (alpha = 0.05).

King No-Mixing Atlantic MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	7079.75			
Year	25	6884.12	195.6	19.9%	< 0.001
Year Area	2	6858.50	25.6	2.6%	< 0.001
Year Area Season	3	6494.57	363.9	37.0%	< 0.001
Year Area Season Mode	1	6413.09	81.5	8.3%	< 0.001
Year Area Season Mode Region	1	6394.48	18.6	1.9%	< 0.001
Year Area Season Mode Region Guild	2	6255.06	139.4	14.2%	< 0.001
Year Area Season Mode Region Guild Region*Guild	2	6253.53	1.5	0.2%	0.465
Year Area Season Mode Region Guild Area*Mode	2	6251.93	3.1	0.3%	0.209
Year Area Season Mode Region Guild Mode*Region	1	6251.16	3.9	0.4%	0.048
Year Area Season Mode Region Guild Area*Region	2	6249.21	5.8	0.6%	0.054
Year Area Season Mode Region Guild Season*Guild	6	6248.70	6.4	0.6%	0.384
Year Area Season Mode Region Guild Year*Region	20	6243.56	11.5	1.2%	0.932
Year Area Season Mode Region Guild Area*Guild	3	6243.36	11.7	1.2%	0.008
Year Area Season Mode Region Guild Mode*Guild	2	6240.53	14.5	1.5%	< 0.001
Year Area Season Mode Region Guild Area*Season	5	6227.81	27.3	2.8%	< 0.001
Year Area Season Mode Region Guild Season*Mode	3	6221.70	33.4	3.4%	< 0.001
Year Area Season Mode Region Guild Year*Area	39	6181.04	74.0	7.5%	< 0.001
Year Area Season Mode Region Guild Year*Mode	25	6176.02	79.0	8.0%	< 0.001
Year Area Season Mode Region Guild Year*Guild	46	6138.81	116.3	11.8%	< 0.001
Year Area Season Mode Region Guild Year*Season	66	6095.43	159.6	16.2%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	24217.1026			
Year	25	22846.1999	1370.9	6.5%	< 0.001
Year Area	2	9212.82857	13633.4	64.9%	< 0.001
Year Area Season	3	8832.40694	380.4	1.8%	< 0.001
Year Area Season Mode	1	8815.2041	17.2	0.1%	< 0.001
Year Area Season Mode Region	1	4018.20056	4797.0	22.8%	< 0.001
Year Area Season Mode Region Guild	2	3330.31905	687.9	3.3%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	3255.37917	74.9	0.4%	< 0.001
Year Area Season Mode Region Guild Area*Mode	2	3208.20255	122.1	0.6%	< 0.001

Table 6. Analyses of mixed model formulations for Atlantic no mix zone king catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models.

King mackerel Atlantic No Mixing zone	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Region Guild	17431.6	17433.6	17439.5		
Year Area Region Guild *Year*Region*	17318.8	17322.8	17326.7	112.8	0.0000
Year Area Region Guild *Year*Region Year*Season*	17183.9	17189.9	17195.7	134.9	0.0000
Positive Catch					
Year Area Season Mode Guild	20237.9	20239.9	20246.9		
Year Area Season Mode Guild *Year*Season*	20178.3	20182.3	20187.5	59.6	0.0000
Year Area Season Mode Guild *Year*Season Year*Mode*	20130.5	20136.5	20144.2	47.8	0.0000
Year Area Season Mode Guild *Year*Season Year*Mode Year*Area*	20110	20118	20128.3	20.5	0.0000
Year Area Season Mode Guild *Year*Season Year*Mode Year*Area Year*guild*	20075.4	20085.4	20098.1	34.6	0.0000

Table 7 Deviance analysis table of explanatory variables in the delta lognormal model for Gulf no mix zone king catch rates (number of fish per thousand angler hours) from the MRFFS data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the Chi-square probability between consecutive models (alpha = 0.05).

Gulf of Mexico no-Mixing King MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	12711.68			
Year	25	12588.54	123.1	6.6%	< 0.001
Year Area	2	12017.92	570.6	30.5%	< 0.001
Year Area Season	3	11788.93	229.0	12.2%	< 0.001
Year Area Season Mode	2	11643.06	145.9	7.8%	< 0.001
Year Area Season Mode Region	2	11553.05	90.0	4.8%	< 0.001
Year Area Season Mode Region Guild	4	11045.58	507.5	27.1%	< 0.001
Year Area Season Mode Region Guild Season*Mode	6	11025.86	19.7	1.1%	0.003
Year Area Season Mode Region Guild Region*Guild	8	11005.29	40.3	2.2%	< 0.001
Year Area Season Mode Region Guild Mode*Guild	8	10991.97	53.6	2.9%	< 0.001
Year Area Season Mode Region Guild Area*Guild	8	10985.48	60.1	3.2%	< 0.001
Year Area Season Mode Region Guild Area*Region	4	10984.16	61.4	3.3%	< 0.001
Year Area Season Mode Region Guild Season*Guild	12	10961.97	83.6	4.5%	< 0.001
Year Area Season Mode Region Guild Year*Mode	49	10957.93	87.6	4.7%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	10932.58	113.0	6.0%	< 0.001
Year Area Season Mode Region Guild Year*Guild	87	10931.45	114.1	6.1%	0.027
Year Area Season Mode Region Guild Mode*Region	4	10919.65	125.9	6.7%	< 0.001
Year Area Season Mode Region Guild Year*Region	50	10902.23	143.3	7.7%	< 0.001
Year Area Season Mode Region Guild Area*Mode	3	10890.89	154.7	8.3%	< 0.001
Year Area Season Mode Region Guild Year*Area	46	10890.17	155.4	8.3%	< 0.001
Year Area Season Mode Region Guild Year*Season	74	10838.68	206.9	11.0%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	40428.5988			
Year	25	39095.856	1332.7	4.6%	< 0.001
Year Area	2	23889.0451	15206.8	52.0%	< 0.001
Year Area Season	3	23546.7656	342.3	1.2%	< 0.001
Year Area Season Mode	2	19017.7147	4529.1	15.5%	< 0.001
Year Area Season Mode Region	2	18262.3258	755.4	2.6%	< 0.001
Year Area Season Mode Region Guild	4	12321.7212	5940.6	20.3%	< 0.001
Year Area Season Mode Region Guild Year*Mode	50	12015.1463	306.6	1.0%	< 0.001
Year Area Season Mode Region Guild Year*Area	50	11929.6098	392.1	1.3%	< 0.001
Year Area Season Mode Region Guild Area*Season	6	11925.705	396.0	1.4%	< 0.001
Year Area Season Mode Region Guild Year*Region	50	11913.0567	408.7	1.4%	< 0.001
Year Area Season Mode Region Guild Year*Guild	100	11730.2087	591.5	2.0%	< 0.001
Year Area Season Mode Region Guild Year*Season	74	11637.5644	684.2	2.3%	< 0.001
Year Area Season Mode Region Guild Area*Mode	3	11195.5019	1126.2	3.9%	< 0.001

Table 8 Analyses of mixed model formulations for Gulf no mix zone king catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models.

Gulf of Mexico no-mixing king mackerel	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Mode Guild	58150.1	58152.1	58159.1		
Year Area Mode Guild *Year*Season*	57824.1	57828.1	57833.3	326	0.0000
Positive Catch					
Year Area Season Mode Region Guild	34021.6	34023.6	34031.1		
Year Area Season Mode Region Guild *Year*Season*	33949	33953	33958.2	72.6	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode*	33931.5	33937.5	33945.4	17.5	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region*	33909.3	33917.3	33927.8	22.2	0.0000
Year Area Season Mode Region Guild *Year*Season Year*Mode Year*Region Year*area*	33851.2	33861.2	33874.3	58.1	0.0000

Table 9. Deviance analysis table of explanatory variables in the delta lognormal model for the mixing zone king catch rates (number of fish per thousand angler hours) from the MRFFS data. Percent of total deviance refers to the deviance explained by the full model; *p* value refers to the Chi-square probability between consecutive models (alpha = 0.05).

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Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4637.08			
Year	25	4503.71	133.4	30.7%	< 0.001
Year Area	2	4440.43	63.3	14.6%	< 0.001
Year Area Season	3	4397.34	43.1	9.9%	< 0.001
Year Area Season Mode	3	4368.17	29.2	6.7%	< 0.001
Year Area Season Mode Guild	2	4321.62	46.5	10.7%	< 0.001
Year Area Season Mode Guild Area*Mode	4	4320.91	0.7	0.2%	0.949
Year Area Season Mode Guild Area*Guild	4	4319.40	2.2	0.5%	0.694
Year Area Season Mode Guild Season*Mode	9	4316.08	5.5	1.3%	0.784
Year Area Season Mode Guild Area*Season	6	4315.79	5.8	1.3%	0.442
Year Area Season Mode Guild Mode*Guild	6	4314.79	6.8	1.6%	0.336
Year Area Season Mode Guild Season*Guild	6	4313.50	8.1	1.9%	0.229
Year Area Season Mode Guild Year*Area	43	4285.16	36.5	8.4%	0.749
Year Area Season Mode Guild Year*Guild	50	4278.97	42.7	9.8%	0.760
Year Area Season Mode Guild Year*Mode	46	4270.04	51.6	11.9%	0.265
Year Area Season Mode Guild Year*Season	73	4202.25	119.4	27.5%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	19154.1537			
Year	25	18570.5397	583.6	3.7%	< 0.001
Year Area	2	10656.8573	7913.7	50.8%	< 0.001
Year Area Season	3	10550.5212	106.3	0.7%	< 0.001
Year Area Season Mode	3	4470.44659	6080.1	39.1%	< 0.001
Year Area Season Mode Guild	2	4063.379	407.1	2.6%	< 0.001
Year Area Season Mode Guild Area*Season	6	4048.32776	15.1	0.1%	0.020
Year Area Season Mode Guild Year*Guild	50	3937.30296	126.1	0.8%	< 0.001
Year Area Season Mode Guild Year*Area	50	3793.99061	269.4	1.7%	< 0.001
Year Area Season Mode Guild Year*Mode	54	3781.60117	281.8	1.8%	< 0.001
Year Area Season Mode Guild Area*Mode	5	3759.77554	303.6	2.0%	< 0.001
Year Area Season Mode Guild Year*Season	74	3588.1113	475.3	3.1%	< 0.001

Table 10. Analyses of mixed model formulations for the mixing zone king catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models.

King mackerel Mixing Zone	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Season Mode	12154.5	12156.5	12162.1		
Year Area Season Mode *Year*Season*	12111.1	12115.1	12120.3	43.4	0.0000
Year Area Season Mode *Year*Season Year*Mode*	12026.4	12032.4	12040.3	84.7	0.0000
Positive Catch					
Year Area Season Mode Guild	18803.8	18805.8	18812.9		
Year Area Season Mode Guild *Year*Season*	18713.9	18717.9	18732.2	89.9	0.0000
Year Area Season Mode Guild *Year*Season Year*Mode*	18685	18691	18698.9	28.9	0.0000
Year Area Season Mode Guild *Year*Season Year*Mode Year*Guild*	18681.2	18689.2	18699.7	3.8	0.0513

Table 11. Nominal and standardized Atlantic king CPUE series from the MRFSS data. Fishing year Atlantic king is April through March of following calendar year.

FYear	N obs	Nominal	ndardized	Coeff Var	Index	confidence	intervals
1981	1152	14.705	5.249	54.5%	1.010	0.364	2.801
1982	2528	19.826	7.206	45.2%	1.386	0.586	3.282
1983	1757	22.212	7.015	46.9%	1.350	0.553	3.295
1984	2283	14.241	6.624	45.3%	1.275	0.537	3.023
1985	2963	14.181	7.142	47.4%	1.374	0.558	3.382
1986	6500	22.544	9.939	41.0%	1.912	0.869	4.210
1987	9758	25.497	6.594	41.7%	1.269	0.570	2.826
1988	9825	18.407	4.950	40.9%	0.952	0.434	2.092
1989	10354	12.673	3.887	41.1%	0.748	0.339	1.649
1990	10139	17.858	6.087	41.0%	1.171	0.533	2.576
1991	10709	19.137	5.659	40.3%	1.089	0.501	2.366
1992	12415	20.050	5.778	39.9%	1.112	0.516	2.396
1993	10697	12.222	3.328	41.4%	0.640	0.289	1.418
1994	13496	9.536	2.863	41.2%	0.551	0.249	1.217
1995	14503	11.781	3.421	40.6%	0.658	0.301	1.439
1996	18088	11.379	3.990	40.2%	0.768	0.354	1.665
1997	16715	14.349	5.163	40.1%	0.993	0.459	2.152
1998	15634	14.066	4.632	39.9%	0.891	0.413	1.924
1999	14170	14.768	4.281	40.1%	0.824	0.381	1.783
2000	16210	17.983	5.389	39.5%	1.037	0.484	2.222
2001	18974	11.047	3.077	40.1%	0.592	0.274	1.282
2002	17082	15.779	3.751	40.0%	0.722	0.334	1.559
2003	14572	15.091	3.896	40.3%	0.750	0.345	1.630
2004	13521	16.823	5.130	39.8%	0.987	0.458	2.126
2005	13473	15.758	5.193	39.9%	0.999	0.463	2.155
2006	13501	15.787	4.882	40.6%	0.939	0.430	2.051

Table 12. Nominal and standardized Gulf king CPUE series from the MRFSS data. Fishing year Gulf king is July through June of following calendar year.

FYear	N obs	Nominal	Standard	Coeff Var	Index	95% confidence	intervals
1981	5032	4.645	0.826	40.5%	0.670	0.307	1.462
1982	8928	2.614	0.444	40.3%	0.360	0.166	0.782
1983	7143	6.080	0.986	36.0%	0.800	0.398	1.608
1984	7077	2.613	0.514	40.1%	0.417	0.193	0.904
1985	9380	2.241	0.526	38.9%	0.427	0.201	0.903
1986	16020	3.498	0.559	32.0%	0.454	0.243	0.847
1987	14184	11.193	1.318	28.6%	1.069	0.611	1.873
1988	17129	5.099	0.834	29.8%	0.677	0.377	1.213
1989	11369	7.127	1.155	30.5%	0.938	0.516	1.703
1990	11105	9.637	1.580	28.6%	1.282	0.731	2.247
1991	15790	7.831	1.454	27.8%	1.180	0.684	2.036
1992	26380	6.907	1.504	26.6%	1.221	0.724	2.058
1993	26383	4.599	1.402	27.2%	1.138	0.666	1.943
1994	27672	6.842	1.773	26.3%	1.439	0.858	2.414
1995	23191	4.545	1.230	28.5%	0.998	0.571	1.745
1996	25941	6.551	1.663	27.1%	1.350	0.793	2.298
1997	27666	10.344	2.020	25.9%	1.640	0.985	2.729
1998	42310	7.656	1.116	26.5%	0.906	0.538	1.524
1999	40284	7.779	1.087	26.3%	0.882	0.526	1.480
2000	43264	11.451	1.384	25.6%	1.123	0.679	1.858
2001	43125	9.404	1.255	25.9%	1.019	0.612	1.695
2002	46176	11.283	1.614	25.3%	1.310	0.796	2.157
2003	43653	7.774	1.126	26.2%	0.914	0.545	1.531
2004	46101	7.312	1.238	26.0%	1.005	0.603	1.675
2005	40515	7.730	1.131	26.4%	0.918	0.546	1.543
2006	30398	11.290	2.298	27.0%	1.865	1.096	3.172

Table 13. Nominal and standardized Atlantic no mix zone king CPUE series from the MRFSS data (calendar year).

Year	N obs	Nominal	Standard	Coeff Var	Index	confidence	intervals
1981	4665	1.763	0.697	72.3%	1.194	0.327	4.365
1982	4862	4.030	0.810	65.0%	1.386	0.423	4.547
1983	6539	1.788	0.815	67.1%	1.396	0.412	4.727
1984	3379	4.577	0.868	64.8%	1.487	0.455	4.859
1985	7876	4.396	0.817	61.1%	1.399	0.454	4.317
1986	11934	10.056	2.583	53.2%	4.424	1.631	12.001
1987	12534	18.464	0.993	57.5%	1.700	0.584	4.948
1988	11896	12.472	0.702	57.6%	1.202	0.412	3.507
1989	17711	5.651	0.562	56.5%	0.962	0.336	2.754
1990	20319	6.783	0.513	59.1%	0.879	0.294	2.625
1991	21791	6.787	0.696	56.8%	1.193	0.414	3.433
1992	20959	7.173	0.552	57.6%	0.946	0.324	2.761
1993	17953	4.345	0.320	64.5%	0.548	0.169	1.783
1994	21106	3.868	0.207	67.9%	0.355	0.104	1.215
1995	17129	6.034	0.233	68.1%	0.399	0.116	1.372
1996	21868	4.124	0.200	67.7%	0.342	0.100	1.168
1997	23970	8.548	0.657	56.9%	1.126	0.390	3.248
1998	21634	4.948	0.318	61.7%	0.544	0.175	1.696
1999	17927	5.125	0.547	59.0%	0.937	0.314	2.795
2000	18035	8.175	0.473	60.5%	0.811	0.265	2.478
2001	24892	3.857	0.238	66.0%	0.407	0.122	1.357
2002	20896	1.711	0.110	77.9%	0.188	0.047	0.745
2003	20758	2.692	0.158	71.7%	0.271	0.075	0.983
2004	19866	3.792	0.270	64.9%	0.462	0.141	1.513
2005	18299	4.772	0.492	57.7%	0.843	0.289	2.464
2006	18368	4.434	0.349	62.1%	0.598	0.191	1.873

Table 14. Nominal and standardized Gulf no mix zone king CPUE series from the MRFSS data (calendar year).

Year	N obs	Nominal	Standard	Coeff Var	Index	5% confidence	interva
1981	4295	5.205	0.885	42.4%	0.722	0.320	1.629
1982	7685	2.986	0.572	40.7%	0.467	0.213	1.022
1983	5104	6.359	1.082	42.8%	0.883	0.389	2.007
1984	6094	3.504	0.614	39.0%	0.501	0.236	1.063
1985	6846	2.337	0.674	41.7%	0.550	0.247	1.226
1986	13849	3.418	0.552	33.8%	0.451	0.233	0.870
1987	13216	11.783	1.319	30.3%	1.077	0.595	1.948
1988	14570	5.013	0.870	32.4%	0.710	0.377	1.336
1989	10592	6.866	1.130	33.2%	0.922	0.483	1.763
1990	8984	8.819	1.583	31.8%	1.292	0.695	2.404
1991	10859	9.606	1.547	30.1%	1.263	0.701	2.276
1992	23327	5.944	1.227	29.3%	1.002	0.564	1.779
1993	20262	4.218	1.222	30.1%	0.998	0.553	1.800
1994	23083	6.340	1.523	29.0%	1.243	0.705	2.194
1995	20781	4.611	1.365	30.5%	1.115	0.614	2.023
1996	21518	5.622	1.619	29.9%	1.322	0.736	2.375
1997	22571	8.227	1.813	28.5%	1.480	0.846	2.588
1998	28549	7.459	1.327	28.6%	1.083	0.618	1.896
1999	39478	8.466	1.130	28.1%	0.922	0.532	1.600
2000	36929	11.457	1.486	27.6%	1.213	0.706	2.085
2001	36712	10.022	1.364	28.0%	1.114	0.643	1.929
2002	38226	10.062	1.518	27.6%	1.239	0.721	2.130
2003	38795	8.192	1.184	28.1%	0.967	0.557	1.680
2004	40057	7.200	1.248	28.1%	1.019	0.587	1.769
2005	35262	6.720	1.054	29.0%	0.860	0.487	1.518
2006	34053	10.741	1.940	27.6%	1.584	0.921	2.724

Table 15. Nominal and standardized mixing zone king CPUE series from the MRFSS data (calendar year).

Year	N obs	Nominal	Standard	Coeff Var	Index	confidence intervals	
1981	1525	7.697	2.382	39.3%	0.630	0.295	1.343
1982	3567	12.807	4.469	29.4%	1.181	0.664	2.101
1983	3904	10.830	2.489	28.4%	0.658	0.377	1.148
1984	4839	15.123	2.763	25.9%	0.730	0.439	1.215
1985	3958	11.163	2.832	32.9%	0.748	0.394	1.420
1986	4058	8.588	2.048	30.4%	0.541	0.299	0.981
1987	3847	6.139	2.218	32.3%	0.586	0.312	1.100
1988	5151	9.223	2.781	27.3%	0.735	0.430	1.256
1989	4458	8.757	2.336	27.3%	0.617	0.361	1.056
1990	4213	16.111	4.695	25.5%	1.241	0.751	2.049
1991	4914	13.448	3.757	26.0%	0.993	0.595	1.656
1992	9474	12.879	3.757	22.8%	0.993	0.633	1.557
1993	10729	10.183	4.959	23.3%	1.310	0.827	2.075
1994	11850	5.623	3.176	24.6%	0.839	0.517	1.363
1995	11100	8.309	4.458	24.0%	1.178	0.734	1.890
1996	9737	11.315	4.681	23.6%	1.237	0.777	1.970
1997	10395	10.868	4.844	22.7%	1.280	0.818	2.003
1998	10711	14.478	5.081	22.1%	1.342	0.868	2.076
1999	13479	15.472	4.908	21.5%	1.297	0.848	1.983
2000	12420	13.847	4.179	21.7%	1.104	0.720	1.694
2001	14443	10.394	2.712	21.7%	0.717	0.467	1.100
2002	17112	11.973	3.303	21.0%	0.873	0.576	1.322
2003	15409	25.396	6.173	20.5%	1.631	1.087	2.447
2004	12104	13.740	3.689	21.8%	0.975	0.634	1.500
2005	12504	15.704	4.472	21.6%	1.182	0.771	1.810
2006	14346	15.923	5.233	21.0%	1.383	0.912	2.096

Table 16. Nominal and standardized Atlantic no mix zone king CPUE series by year and season from the MRFSS data

Year	Season	N obs	Nominal	Standard	Coeff Var	Index	confidence intervals	
1981	JanMar	.	.	.	.	.	.	.
1981	AprJun	1415	1.474	0.418	90.1%	0.604	0.129	2.820
1981	JulOct	2460	0.548	0.234	110.9%	0.337	0.056	2.023
1981	NovDec	790	6.065	3.647	96.4%	5.268	1.042	26.642
1982	JanMar	22	0.000	.	.	.	.	.
1982	AprJun	1219	8.640	1.101	74.4%	1.590	0.421	5.996
1982	JulOct	2937	1.142	0.468	85.3%	0.676	0.154	2.968
1982	NovDec	685	8.337	1.590	76.7%	2.297	0.589	8.950
1983	JanMar	31	0.000	.	.	.	.	.
1983	AprJun	2717	1.177	0.320	92.9%	0.462	0.095	2.236
1983	JulOct	3076	2.127	1.191	70.9%	1.721	0.480	6.163
1983	NovDec	715	2.727	1.453	95.4%	2.099	0.420	10.495
1984	JanMar	46	0.000	.	.	.	.	.
1984	AprJun	1366	2.735	0.420	81.5%	0.607	0.146	2.531
1984	JulOct	1503	4.179	0.932	71.2%	1.346	0.374	4.847
1984	NovDec	464	11.744	2.510	80.3%	3.625	0.884	14.866
1985	JanMar	162	0.000	.	.	.	.	.
1985	AprJun	2966	4.129	0.696	70.4%	1.005	0.282	3.574
1985	JulOct	3639	3.589	1.001	66.8%	1.445	0.429	4.872
1985	NovDec	1109	8.400	1.947	77.2%	2.813	0.717	11.033
1986	JanMar	369	6.489	5.470	92.0%	7.901	1.650	37.838
1986	AprJun	4007	8.528	1.508	62.3%	2.178	0.693	6.843
1986	JulOct	5552	9.725	2.201	56.4%	3.179	1.111	9.099
1986	NovDec	2007	14.670	3.997	59.5%	5.773	1.919	17.369
1987	JanMar	304	0.000	.	.	.	.	.
1987	AprJun	3514	19.956	1.065	63.4%	1.538	0.481	4.918
1987	JulOct	6703	15.365	0.940	59.8%	1.358	0.449	4.105
1987	NovDec	2013	28.969	1.615	66.9%	2.333	0.691	7.873
1988	JanMar	270	0.000	.	.	.	.	.
1988	AprJun	3642	14.267	0.768	65.0%	1.109	0.338	3.637
1988	JulOct	6116	11.017	0.738	58.8%	1.066	0.358	3.172
1988	NovDec	1868	15.536	0.830	67.6%	1.199	0.352	4.089
1989	JanMar	413	0.000	.	.	.	.	.
1989	AprJun	4846	5.396	0.855	57.0%	1.235	0.428	3.566
1989	JulOct	9102	3.912	0.264	66.6%	0.382	0.114	1.283
1989	NovDec	3357	11.417	0.868	65.4%	1.254	0.380	4.137
1990	JanMar	313	9.264	0.981	96.8%	1.417	0.278	7.207
1990	AprJun	6428	2.870	0.257	72.8%	0.371	0.101	1.369
1990	JulOct	10319	6.347	0.473	62.1%	0.683	0.218	2.139
1990	NovDec	3260	15.638	1.152	65.6%	1.664	0.503	5.507
1991	JanMar	298	0.000	.	.	.	.	.
1991	AprJun	7565	5.250	0.327	69.8%	0.473	0.134	1.666
1991	JulOct	9772	5.911	0.839	55.8%	1.211	0.428	3.432
1991	NovDec	4160	12.139	0.969	65.7%	1.400	0.422	4.642
1992	JanMar	331	5.275	0.418	113.4%	0.604	0.098	3.722
1992	AprJun	6849	4.572	0.280	71.6%	0.404	0.111	1.463
1992	JulOct	9843	5.726	0.698	57.9%	1.008	0.344	2.956
1992	NovDec	3951	15.432	0.962	66.6%	1.389	0.414	4.665
1993	JanMar	255	1.307	0.174	218.0%	0.251	0.018	3.540
1993	AprJun	5514	2.765	0.157	82.9%	0.226	0.053	0.961
1993	JulOct	8464	2.423	0.248	69.5%	0.358	0.102	1.257
1993	NovDec	3738	11.213	0.766	69.7%	1.106	0.314	3.891
1994	JanMar	287	0.106	0.004	851.5%	0.005	0.000	0.339
1994	AprJun	6905	3.014	0.159	79.7%	0.230	0.057	0.936
1994	JulOct	9961	2.632	0.203	72.6%	0.294	0.080	1.079
1994	NovDec	3959	8.737	0.375	72.8%	0.541	0.147	1.993
1995	JanMar	394	3.173	0.150	223.2%	0.217	0.015	3.152
1995	AprJun	5520	3.041	0.115	88.9%	0.166	0.036	0.761
1995	JulOct	7078	4.378	0.258	71.8%	0.372	0.103	1.352
1995	NovDec	4140	13.123	0.619	70.3%	0.894	0.252	3.173
1996	JanMar	2137	2.578	0.041	130.7%	0.059	0.008	0.438
1996	AprJun	7453	3.960	0.194	75.9%	0.281	0.073	1.082
1996	JulOct	8012	3.514	0.228	75.2%	0.329	0.086	1.254
1996	NovDec	4269	6.322	0.499	72.8%	0.721	0.196	2.657
1997	JanMar	3067	14.162	0.234	80.9%	0.338	0.082	1.398
1997	AprJun	7196	6.038	0.279	73.4%	0.403	0.108	1.497
1997	JulOct	9039	7.123	0.884	61.2%	1.277	0.413	3.945
1997	NovDec	4668	11.487	1.602	62.1%	2.314	0.739	7.249
1998	JanMar	2018	5.137	0.110	102.1%	0.158	0.029	0.858
1998	AprJun	6322	5.578	0.302	72.5%	0.437	0.119	1.603
1998	JulOct	8416	2.199	0.289	69.4%	0.417	0.119	1.461
1998	NovDec	4878	8.795	0.773	66.5%	1.117	0.333	3.747
1999	JanMar	534	9.718	0.277	90.7%	0.399	0.085	1.881
1999	AprJun	5420	4.276	0.361	72.9%	0.521	0.141	1.925
1999	JulOct	8110	4.396	0.563	61.6%	0.813	0.261	2.531
1999	NovDec	3863	7.210	0.536	71.0%	0.774	0.216	2.777
2000	JanMar	557	1.120	0.032	195.0%	0.046	0.004	0.564
2000	AprJun	5915	6.348	0.292	74.5%	0.422	0.112	1.593
2000	JulOct	7812	7.623	0.844	61.6%	1.220	0.392	3.794
2000	NovDec	3754	13.273	0.782	68.4%	1.130	0.327	3.899
2001	JanMar	645	4.841	0.243	103.3%	0.350	0.064	1.926
2001	AprJun	7864	5.395	0.305	72.4%	0.440	0.120	1.612
2001	JulOct	10181	2.722	0.275	69.6%	0.397	0.113	1.393
2001	NovDec	6202	3.670	0.264	77.1%	0.382	0.097	1.498
2002	JanMar	1908	0.547	0.014	235.6%	0.020	0.001	0.316
2002	AprJun	6912	1.833	0.156	82.5%	0.226	0.053	0.955
2002	JulOct	8294	1.758	0.167	78.5%	0.242	0.060	0.967
2002	NovDec	3782	1.975	0.239	82.7%	0.345	0.081	1.461
2003	JanMar	1511	0.624	0.022	222.8%	0.032	0.002	0.467
2003	AprJun	6867	2.235	0.172	81.0%	0.248	0.060	1.026
2003	JulOct	7999	3.216	0.309	70.5%	0.446	0.125	1.589
2003	NovDec	4381	3.164	0.237	83.0%	0.342	0.080	1.454
2004	JanMar	1282	0.520	0.036	216.9%	0.052	0.004	0.725
2004	AprJun	6164	3.937	0.370	70.8%	0.535	0.150	1.914
2004	JulOct	6678	2.559	0.279	72.2%	0.403	0.110	1.473
2004	NovDec	5747	5.795	0.613	68.4%	0.885	0.256	3.056
2005	JanMar	1218	0.041	0.002	1150.4%	0.003	0.000	0.240
2005	AprJun	5692	3.999	0.275	74.0%	0.397	0.106	1.490
2005	JulOct	6962	6.996	1.324	55.0%	1.912	0.683	5.351
2005	NovDec	4427	3.570	0.380	75.5%	0.549	0.143	2.104
2006	JanMar	1153	4.629	0.281	89.2%	0.405	0.088	1.871
2006	AprJun	5795	5.639	0.315	72.1%	0.455	0.125	1.660
2006	JulOct	6227	2.491	0.316	69.7%	0.456	0.130	1.604
2006	NovDec	5194	5.374	0.424	72.4%	0.612	0.167	2.242

Table 17. Nominal and standardized Gulf no mix zone king CPUE series by year and season from the MRFSS data

Year	Season	N obs	Nominal	Standard	Coeff Var	Index	95% confidence interva	
1981	JanMar	.	.	.	.	.	.	.
1981	AprJun	942	5.811	0.874	56.5%	0.719	0.251	2.061
1981	JulOct	1692	9.239	1.248	46.7%	1.027	0.422	2.500
1981	NovDec	1661	0.752	0.200	103.8%	0.164	0.030	0.909
1982	JanMar	383	0.837	0.234	157.0%	0.193	0.021	1.791
1982	AprJun	2814	3.191	0.434	48.7%	0.358	0.142	0.900
1982	JulOct	2663	2.632	0.598	51.0%	0.493	0.188	1.288
1982	NovDec	1827	3.634	0.861	75.7%	0.708	0.184	2.721
1983	JanMar	753	0.489	0.074	181.5%	0.061	0.005	0.681
1983	AprJun	2081	10.107	1.498	54.7%	1.233	0.443	3.429
1983	JulOct	1269	7.070	1.176	54.8%	0.968	0.348	2.696
1983	NovDec	1002	2.078	0.775	90.2%	0.638	0.136	2.987
1984	JanMar	1203	6.129	1.303	57.7%	1.072	0.367	3.134
1984	AprJun	1965	2.678	0.290	74.3%	0.239	0.063	0.898
1984	JulOct	1701	3.100	0.449	55.1%	0.369	0.132	1.035
1984	NovDec	1229	2.801	0.957	61.4%	0.788	0.254	2.442
1985	JanMar	866	1.834	0.394	102.6%	0.324	0.059	1.767
1985	AprJun	1926	1.543	0.374	70.6%	0.308	0.086	1.097
1985	JulOct	2012	2.580	0.684	56.0%	0.563	0.198	1.599
1985	NovDec	2043	3.058	1.212	59.9%	0.998	0.330	3.021
1986	JanMar	1939	0.996	0.203	105.2%	0.167	0.030	0.940
1986	AprJun	3894	1.122	0.237	50.6%	0.195	0.075	0.506
1986	JulOct	4413	6.021	0.881	36.1%	0.725	0.360	1.461
1986	NovDec	3613	4.003	0.666	39.4%	0.548	0.256	1.172
1987	JanMar	2271	2.578	0.510	58.9%	0.419	0.141	1.249
1987	AprJun	4393	16.171	1.450	28.4%	1.193	0.683	2.084
1987	JulOct	4294	16.973	2.198	27.8%	1.809	1.048	3.123
1987	NovDec	2271	2.723	0.739	57.9%	0.608	0.208	1.782
1988	JanMar	1997	1.753	0.545	109.2%	0.449	0.076	2.640
1988	AprJun	2773	1.423	0.265	56.3%	0.218	0.077	0.624
1988	JulOct	4871	9.852	1.618	29.6%	1.331	0.746	2.375
1988	NovDec	4962	3.550	0.809	38.1%	0.666	0.319	1.390
1989	JanMar	2572	1.344	0.354	83.5%	0.291	0.068	1.247
1989	AprJun	2737	3.741	0.487	47.8%	0.401	0.162	0.993
1989	JulOct	3369	13.767	1.704	34.1%	1.403	0.722	2.725
1989	NovDec	1970	6.418	1.792	45.0%	1.475	0.625	3.481
1990	JanMar	1678	2.548	0.762	60.8%	0.627	0.204	1.924
1990	AprJun	2667	7.860	1.366	38.2%	1.124	0.538	2.350
1990	JulOct	2598	12.310	1.899	35.1%	1.563	0.790	3.092
1990	NovDec	2076	10.604	1.971	41.3%	1.622	0.734	3.586
1991	JanMar	2011	6.967	1.177	45.9%	0.969	0.404	2.322
1991	AprJun	3278	3.573	0.680	40.1%	0.560	0.259	1.213
1991	JulOct	2869	20.497	3.240	29.6%	2.667	1.493	4.763
1991	NovDec	2764	7.157	1.369	41.2%	1.126	0.511	2.485
1992	JanMar	4553	3.031	1.178	48.3%	0.969	0.388	2.422
1992	AprJun	7017	5.136	0.948	32.4%	0.780	0.415	1.467
1992	JulOct	5495	8.833	1.707	30.0%	1.405	0.781	2.527
1992	NovDec	6397	6.332	1.507	30.7%	1.241	0.681	2.260
1993	JanMar	4240	2.777	0.874	44.8%	0.719	0.306	1.692
1993	AprJun	5258	2.762	0.801	38.7%	0.659	0.312	1.390
1993	JulOct	6086	5.850	1.580	30.8%	1.301	0.712	2.375
1993	NovDec	4821	4.972	1.362	34.6%	1.121	0.572	2.197
1994	JanMar	5433	4.051	1.313	41.4%	1.080	0.487	2.394
1994	AprJun	6411	5.004	1.035	31.9%	0.852	0.457	1.589
1994	JulOct	6624	8.319	2.176	30.0%	1.791	0.996	3.219
1994	NovDec	4743	7.833	1.958	31.9%	1.612	0.864	3.004
1995	JanMar	5034	8.580	3.225	36.4%	2.655	1.312	5.371
1995	AprJun	5749	4.966	1.086	35.3%	0.894	0.451	1.772
1995	JulOct	6211	2.485	0.871	38.9%	0.717	0.338	1.520
1995	NovDec	4112	2.151	0.582	49.2%	0.479	0.189	1.216
1996	JanMar	3875	6.027	2.094	41.6%	1.723	0.775	3.833
1996	AprJun	6084	7.810	1.390	33.4%	1.144	0.596	2.194
1996	JulOct	5922	4.958	1.530	34.2%	1.260	0.647	2.452
1996	NovDec	5942	3.532	1.309	35.8%	1.078	0.538	2.160
1997	JanMar	4449	7.025	1.842	37.9%	1.516	0.729	3.154
1997	AprJun	6106	3.574	0.888	38.5%	0.731	0.348	1.538
1997	JulOct	6482	10.577	2.408	28.0%	1.982	1.143	3.435
1997	NovDec	5875	11.583	2.271	29.1%	1.869	1.056	3.308
1998	JanMar	5393	14.439	2.669	32.7%	2.197	1.162	4.153
1998	AprJun	6558	4.515	0.677	34.6%	0.557	0.285	1.091
1998	JulOct	7574	5.225	1.217	29.3%	1.002	0.564	1.780
1998	NovDec	9360	7.103	1.184	29.4%	0.974	0.547	1.735
1999	JanMar	11840	10.216	1.950	31.9%	1.605	0.862	2.991
1999	AprJun	11434	5.112	0.626	28.9%	0.515	0.292	0.908
1999	JulOct	9311	7.283	1.128	28.0%	0.928	0.536	1.608
1999	NovDec	7336	12.042	1.087	29.0%	0.895	0.507	1.579
2000	JanMar	7460	6.681	1.153	32.5%	0.949	0.503	1.789
2000	AprJun	12494	7.701	0.820	26.9%	0.675	0.398	1.145
2000	JulOct	9960	18.235	2.521	25.4%	2.074	1.258	3.422
2000	NovDec	7455	13.084	1.769	27.5%	1.456	0.848	2.500
2001	JanMar	8111	11.326	1.604	32.9%	1.320	0.695	2.506
2001	AprJun	11215	7.222	0.731	28.6%	0.602	0.343	1.055
2001	JulOct	10599	11.549	1.644	26.5%	1.353	0.803	2.279
2001	NovDec	7270	10.287	1.609	30.9%	1.325	0.724	2.422
2002	JanMar	8196	12.074	1.882	30.1%	1.549	0.859	2.792
2002	AprJun	11905	8.273	0.990	26.2%	0.814	0.487	1.362
2002	JulOct	10263	13.151	2.219	26.5%	1.826	1.086	3.073
2002	NovDec	8315	6.432	1.117	30.5%	0.919	0.506	1.670
2003	JanMar	8668	9.165	1.710	31.7%	1.407	0.758	2.612
2003	AprJun	12349	7.631	0.813	28.2%	0.669	0.385	1.163
2003	JulOct	10614	9.276	1.387	26.9%	1.142	0.673	1.936
2003	NovDec	7632	6.286	0.979	30.7%	0.806	0.442	1.467
2004	JanMar	8038	5.543	1.095	33.6%	0.902	0.468	1.736
2004	AprJun	12926	6.733	0.953	26.9%	0.784	0.462	1.331
2004	JulOct	10691	9.235	1.478	27.2%	1.216	0.713	2.075
2004	NovDec	9072	6.670	1.165	30.8%	0.959	0.525	1.751
2005	JanMar	8256	5.033	0.906	37.8%	0.745	0.359	1.547
2005	AprJun	12734	10.604	0.998	27.3%	0.822	0.480	1.406
2005	JulOct	8544	5.455	1.098	28.8%	0.904	0.514	1.589
2005	NovDec	6682	2.404	0.502	41.0%	0.413	0.188	0.909
2006	JanMar	6849	8.094	1.225	36.2%	1.009	0.500	2.034
2006	AprJun	10464	11.608	1.681	25.9%	1.383	0.830	2.304
2006	JulOct	9947	16.097	3.025	25.2%	2.490	1.517	4.087
2006	NovDec	7419	4.064	1.043	34.9%	0.858	0.436	1.689

Table 18. Nominal and standardized mixing zone king CPUE series by year and season from the MRFSS data

Year	Season	N obs	Nominal	ndardized	Coeff Var	Index	confidence intervals	
1981	JanMar	.	.	.	.	.	.	.
1981	AprJun	458	7.720	2.079	59.3%	0.521	0.174	1.562
1981	JulOct	525	13.025	3.509	49.4%	0.879	0.345	2.237
1981	NovDec	542	2.516	1.681	106.2%	0.421	0.074	2.394
1982	JanMar	44	0.000	.	.	.	.	.
1982	AprJun	828	11.970	5.566	42.4%	1.394	0.618	3.146
1982	JulOct	1551	12.575	5.553	36.8%	1.391	0.682	2.836
1982	NovDec	1144	14.219	3.920	48.4%	0.982	0.392	2.458
1983	JanMar	685	2.330	0.550	121.2%	0.138	0.021	0.922
1983	AprJun	1514	11.987	1.951	33.1%	0.489	0.257	0.930
1983	JulOct	647	17.769	4.766	45.4%	1.194	0.502	2.837
1983	NovDec	1058	10.436	3.594	54.6%	0.900	0.324	2.502
1984	JanMar	1426	6.754	1.520	45.8%	0.381	0.159	0.910
1984	AprJun	1637	24.866	2.701	33.5%	0.676	0.352	1.299
1984	JulOct	834	11.754	4.136	40.6%	1.036	0.474	2.261
1984	NovDec	942	13.842	3.820	45.3%	0.957	0.403	2.271
1985	JanMar	1693	1.605	0.491	75.3%	0.123	0.032	0.470
1985	AprJun	736	28.500	8.011	49.8%	2.006	0.782	5.145
1985	JulOct	787	20.772	5.594	49.3%	1.401	0.551	3.560
1985	NovDec	742	5.583	1.947	70.1%	0.488	0.138	1.728
1986	JanMar	924	2.207	0.562	82.7%	0.141	0.033	0.596
1986	AprJun	1192	10.241	2.562	40.4%	0.642	0.295	1.397
1986	JulOct	1005	16.953	3.603	39.9%	0.902	0.418	1.948
1986	NovDec	937	3.806	1.199	70.9%	0.300	0.084	1.075
1987	JanMar	1142	4.241	2.232	56.2%	0.559	0.196	1.594
1987	AprJun	1066	9.247	3.247	42.6%	0.813	0.359	1.840
1987	JulOct	935	3.682	1.075	63.9%	0.269	0.084	0.867
1987	NovDec	704	7.772	2.467	62.9%	0.618	0.195	1.959
1988	JanMar	784	5.979	1.928	75.8%	0.483	0.125	1.858
1988	AprJun	1029	9.214	3.639	39.0%	0.911	0.429	1.936
1988	JulOct	1777	11.615	3.211	32.1%	0.804	0.430	1.505
1988	NovDec	1561	8.136	2.562	45.3%	0.642	0.270	1.522
1989	JanMar	981	5.423	1.512	54.2%	0.379	0.137	1.045
1989	AprJun	1075	10.703	2.540	38.2%	0.636	0.304	1.331
1989	JulOct	1498	9.921	2.993	35.5%	0.749	0.376	1.493
1989	NovDec	904	8.131	2.302	46.9%	0.577	0.236	1.407
1990	JanMar	959	5.467	2.441	52.2%	0.611	0.229	1.631
1990	AprJun	1077	16.602	4.250	37.0%	1.064	0.520	2.177
1990	JulOct	1296	20.390	5.770	30.6%	1.445	0.794	2.630
1990	NovDec	881	20.800	7.044	38.2%	1.764	0.843	3.692
1991	JanMar	1104	2.073	0.677	81.7%	0.170	0.041	0.709
1991	AprJun	1408	13.921	3.943	34.0%	0.988	0.510	1.913
1991	JulOct	1457	17.974	4.698	31.0%	1.177	0.642	2.156
1991	NovDec	945	19.055	7.734	40.3%	1.937	0.892	4.205
1992	JanMar	2026	6.603	2.067	38.6%	0.518	0.245	1.092
1992	AprJun	2747	8.318	2.817	32.6%	0.705	0.374	1.331
1992	JulOct	2779	19.367	4.771	23.7%	1.195	0.748	1.909
1992	NovDec	1922	16.635	6.497	29.1%	1.627	0.920	2.877
1993	JanMar	2155	18.146	8.850	29.1%	2.216	1.253	3.922
1993	AprJun	2895	3.347	1.606	41.6%	0.402	0.181	0.894
1993	JulOct	3258	11.049	5.034	27.1%	1.261	0.740	2.148
1993	NovDec	2421	10.105	6.255	32.9%	1.566	0.825	2.974
1994	JanMar	3066	3.181	1.829	40.2%	0.458	0.211	0.993
1994	AprJun	2975	6.034	2.652	33.1%	0.664	0.349	1.265
1994	JulOct	3262	5.449	3.213	33.1%	0.805	0.422	1.533
1994	NovDec	2547	8.306	6.313	34.6%	1.581	0.806	3.099
1995	JanMar	2960	3.961	2.367	42.3%	0.593	0.263	1.334
1995	AprJun	2885	7.987	3.453	31.8%	0.865	0.465	1.610
1995	JulOct	2841	9.176	5.621	30.2%	1.408	0.780	2.540
1995	NovDec	2414	13.006	7.344	32.7%	1.839	0.972	3.481
1996	JanMar	1838	7.074	2.698	39.6%	0.676	0.315	1.449
1996	AprJun	2625	10.610	3.863	28.4%	0.968	0.555	1.688
1996	JulOct	2878	11.255	4.942	29.3%	1.238	0.697	2.199
1996	NovDec	2396	15.413	8.027	33.9%	2.010	1.040	3.884
1997	JanMar	2402	9.014	3.599	32.6%	0.901	0.477	1.702
1997	AprJun	2875	11.306	5.181	27.7%	1.297	0.753	2.237
1997	JulOct	2591	10.576	4.688	30.0%	1.174	0.652	2.113
1997	NovDec	2527	12.431	5.851	28.6%	1.465	0.836	2.568
1998	JanMar	2068	15.025	5.889	30.0%	1.475	0.820	2.652
1998	AprJun	2780	16.183	5.626	26.6%	1.409	0.836	2.376
1998	JulOct	2881	11.235	4.312	28.3%	1.080	0.620	1.881
1998	NovDec	2982	15.641	4.945	26.2%	1.238	0.740	2.073
1999	JanMar	4272	14.467	3.357	27.1%	0.841	0.494	1.431
1999	AprJun	4138	15.177	4.919	22.4%	1.232	0.792	1.916
1999	JulOct	2803	15.805	5.236	25.3%	1.311	0.798	2.156
1999	NovDec	2266	17.490	6.819	29.3%	1.708	0.961	3.034
2000	JanMar	2608	9.538	3.044	30.9%	0.762	0.416	1.395
2000	AprJun	4188	14.131	3.857	22.4%	0.966	0.620	1.505
2000	JulOct	3229	16.473	5.487	23.1%	1.374	0.870	2.170
2000	NovDec	2395	14.505	4.739	31.8%	1.187	0.638	2.206
2001	JanMar	3469	7.446	2.072	29.5%	0.519	0.291	0.925
2001	AprJun	3876	13.220	2.916	24.1%	0.730	0.454	1.176
2001	JulOct	4074	12.160	3.481	23.4%	0.872	0.549	1.385
2001	NovDec	3024	7.773	2.027	29.2%	0.508	0.287	0.899
2002	JanMar	3544	5.713	1.534	31.5%	0.384	0.208	0.711
2002	AprJun	4198	17.688	4.903	21.7%	1.228	0.799	1.887
2002	JulOct	4779	11.558	3.424	22.5%	0.857	0.550	1.336
2002	NovDec	4591	12.013	3.384	23.8%	0.848	0.530	1.356
2003	JanMar	4470	45.985	10.870	20.5%	2.722	1.813	4.088
2003	AprJun	4638	18.995	4.860	21.5%	1.217	0.796	1.860
2003	JulOct	3595	15.438	5.375	23.7%	1.346	0.843	2.149
2003	NovDec	2706	15.587	4.442	27.3%	1.112	0.651	1.901
2004	JanMar	2795	11.578	2.668	30.1%	0.668	0.371	1.205
2004	AprJun	3382	13.536	3.908	24.7%	0.979	0.601	1.593
2004	JulOct	2886	20.646	6.282	24.5%	1.573	0.970	2.551
2004	NovDec	3041	9.399	2.727	28.1%	0.683	0.393	1.185
2005	JanMar	2999	22.577	5.525	26.1%	1.384	0.828	2.313
2005	AprJun	3715	11.252	3.252	25.6%	0.815	0.492	1.349
2005	JulOct	3110	16.285	5.704	24.3%	1.428	0.885	2.306
2005	NovDec	2680	13.512	3.816	28.6%	0.956	0.546	1.674
2006	JanMar	3661	15.166	4.821	24.7%	1.207	0.742	1.964
2006	AprJun	4167	14.149	4.438	23.1%	1.112	0.705	1.753
2006	JulOct	3496	20.911	6.730	22.2%	1.685	1.087	2.613
2006	NovDec	3022	13.514	4.787	28.6%	1.199	0.684	2.102

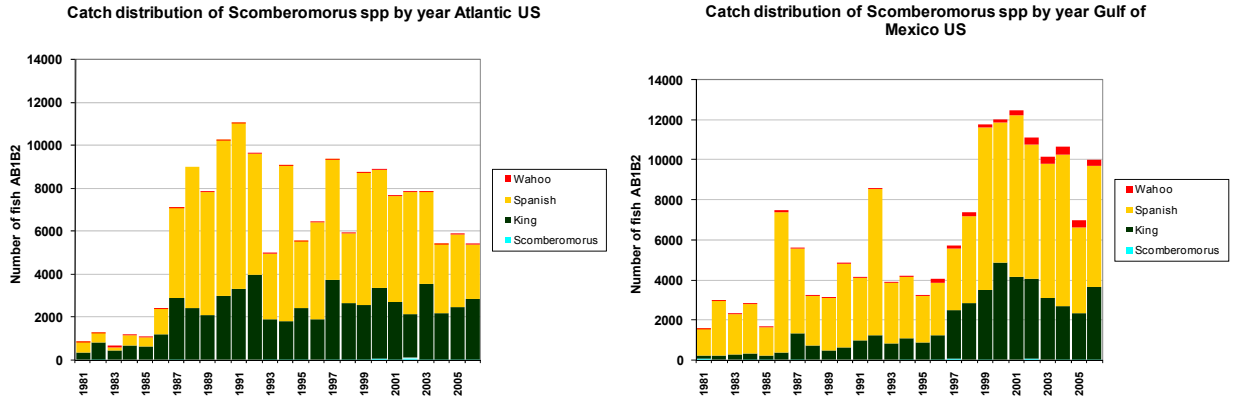

Figure 1. MRFSS reported catch (AB1B2) of mackerels by species and stock unit 1991-2007.

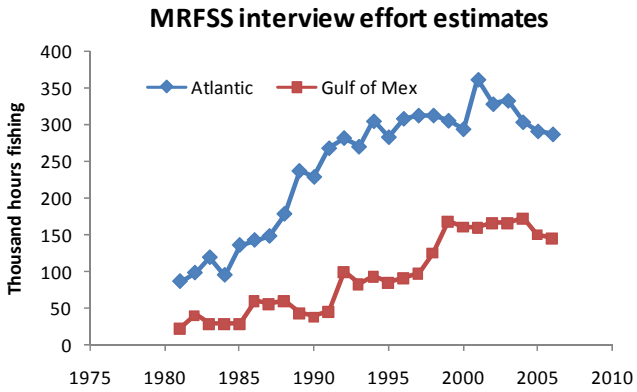

Figure 2. MRFSS reported fishing effort (fishing hours) as number of fishers times hours fishing 1981-2006.

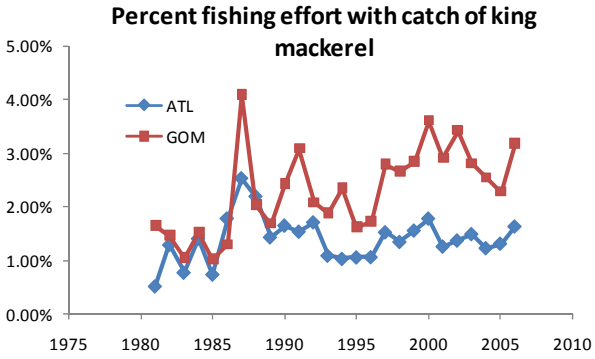

Figure 3 Percent of MRFSS fishing effort that reported catches of king mackerel.

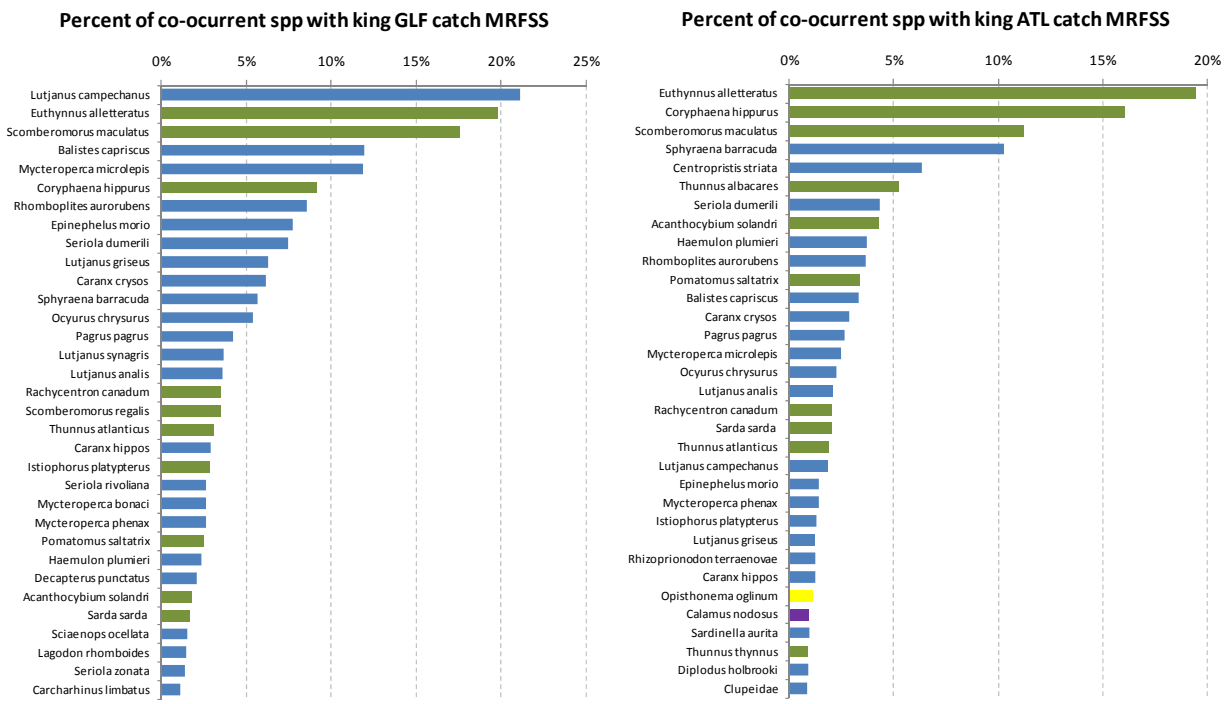

Figure 4. Percent of concurrent species caught with king mackerel by recreational fishers in the Gulf of Mexico (left) and Atlantic waters. Bar colors associated with pelagic guild species (green), reef species (blue), inshore species (yellow), and non-reef species (purple).

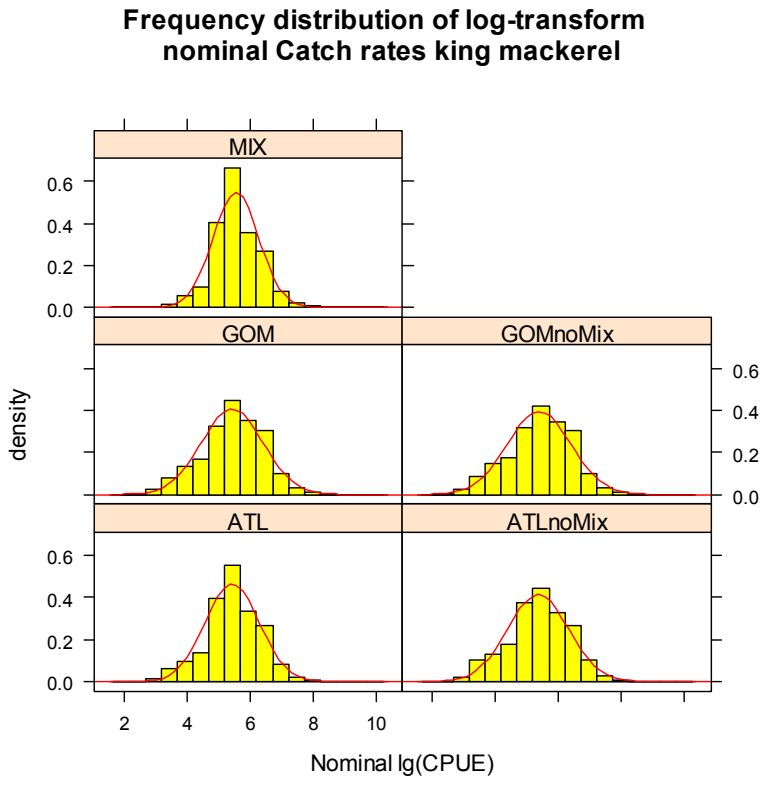

Figure 5 Frequency distribution of log transformed nominal catch rates (CPUE) of king mackerel from recreational MRFSS data 1981-2006.

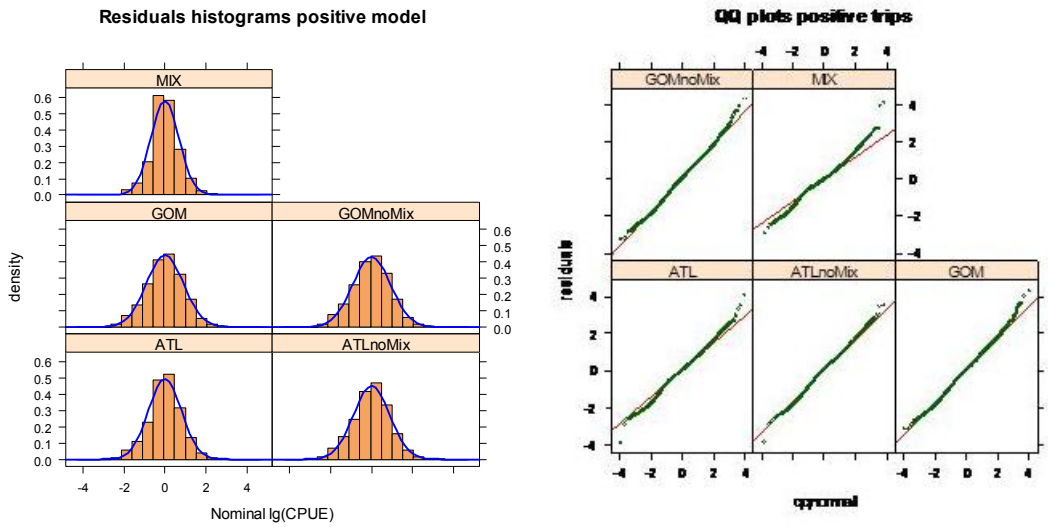

Figure 6. Diagnostic plots fit positive observations lognormal model CPUE king mackerel from recreational MRFSS data 1981-2006. Residuals histograms (left) and normalize cumulative residual plots (qq plots) (right).

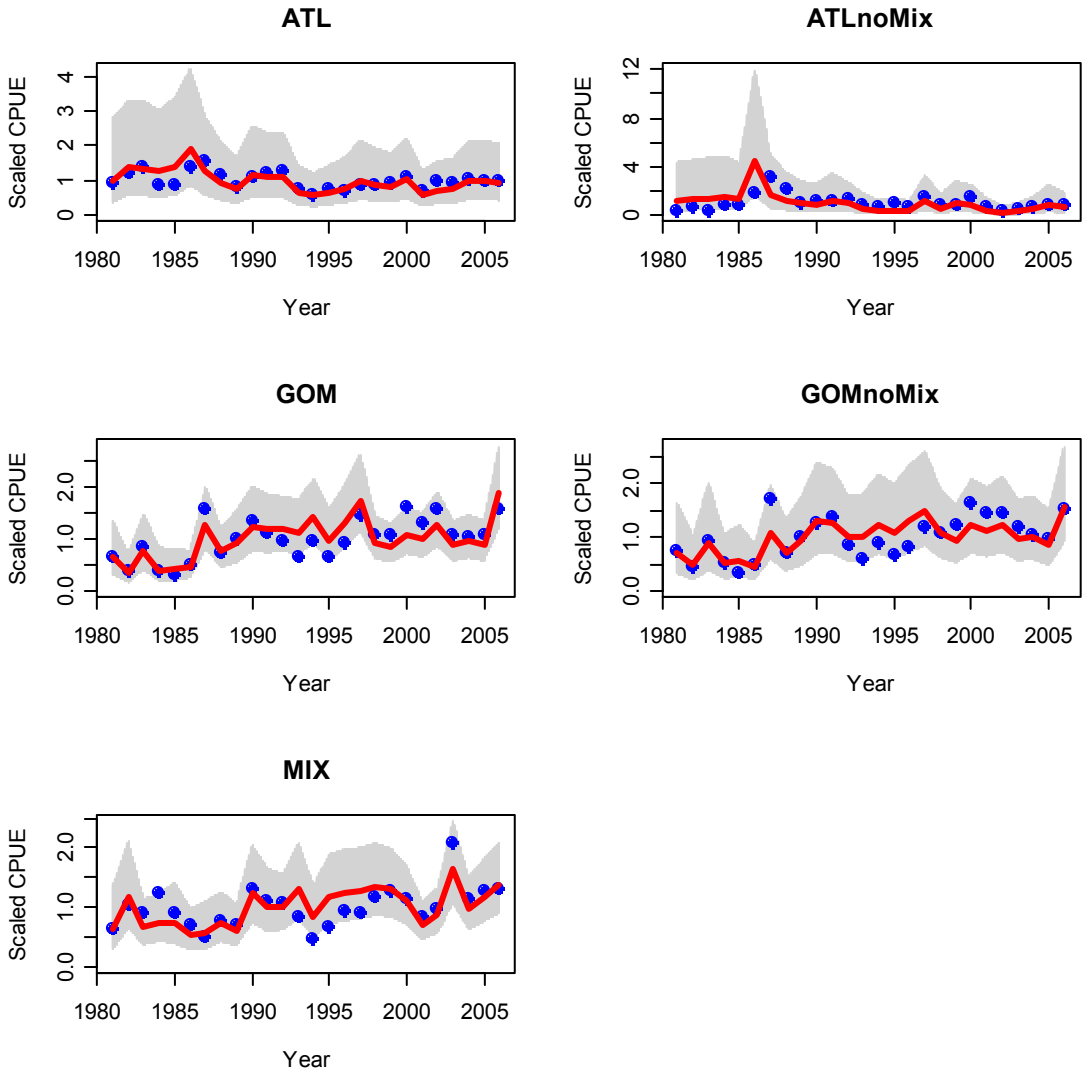

Figure 7. Nominal and standardize CPUE trends for king mackerel stocks by migratory group (ATL, GOM) and regions (ATL no mix, GOM no mix and mixing zone). Shade area represent estimated 95% confidence intervals, for migratory group year correspond to fishing year definition of each migratory group.