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

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SUMMARY

Standardized indices of abundance were estimated for stocks of king and Spanish mackerel in the US Gulf of Mexico and Southeastern US Atlantic from two recreational fisheries data sets; the Marine Recreational Fishery Statistics Survey (MRFSS) of private and charter recreational boats, and the Texas Parks and Wildlife Division Recreational Angler Creel Survey. Estimates of variance components, which better account for uncertainty due to process error and correlation between observations in the data sets, were derived.

Introduction

Information on the relative abundance of mackerel stock is required to tune stock assessment models. Data collected from several commercial and recreational fisheries and fisheries independent surveys have been previously used to develop standardized catch per unit effort (CPUE) indices of abundance for the Gulf of Mexico and South Atlantic king and Spanish mackerel stocks. This report documented analytical methods applied to the available data through fishing year 2002 when available, and presented standardized CPUE indices for king and Spanish mackerel. These indices included estimates of variance which better account for sampling error and correlation between observations in the catch rate analyzed through the application of random effects modeling methods (Cooke, 1997). Catch and effort data collected from recreational fisheries surveys operating in the US Gulf of Mexico and the South Atlantic coast were used to develop the indices of abundance presented herein. Standardized catch rates were estimated using the Generalized Linear Mixed Model (GLMM) approach.

Materials and Methods

Ortiz et al (2002) described the available catch and effort data for king mackerel from the recreational fisheries operating in the US Gulf of Mexico, while Legault et al (1998) described the available catch and effort data for the remaining stocks. Powers et al (1996) described the conventional GLM for analysis of CPUE series. The present analysis was a modified application of GLM analysis, in which observations with fishing effort directed towards king mackerel and or Spanish mackerel were included, instead of including only records with positive catch for either king or Spanish mackerel as in prior analyses (MSAP 1998). Three recreational fisheries surveys data were reviewed and standardized: 1) the MRFSS survey for charter and private recreational boats, 2) the Charter Headboat Survey of vessels operating in the US Gulf of Mexico and South Atlantic coast, and 3) the Texas Parks and Wildlife Recreational Angler Creel Survey of vessels docked or operating off Texas coastal waters.

MRFSS. In 1996, the MSAP decided to include trips that indicated king mackerel as the primary target species, even if they were unsuccessful. In the 1996 assessment analysis of MRFSS Florida Gulf CPUE data, the MSAP selected a Delta lognormal model with a lognormal error distribution for the proportion of positive trips. And, for the subset of positive catch trips, the Panel opted for adding the total catch per stratum (sum of catch per year-bimonth-mode-county cell), and used the number of trips per stratum as a weighting factor in the model specification (MSAP, 1996). To attempt to incorporate a fuller range of fishing effort that had a reasonable

probability of catching king mackerel in the analysis, the MRFSS intercept data were subset into effort that caught or indicated intent to catch a group of species believed to be associated with king mackerel in recreational fishery activities. The associated species used in these analyses were: Spanish mackerel (*S. maculatus*), cero mackerel (*S. regalis*), greater amberjack (*Seriola dumerili*), banded rudderfish (*S. zonata*), almaco jack (*S. rivoliana*), little tunny (*Euthynnus alletteratus*), blackfin tuna (*Thunnus atlanticus*), bonito (*Sarda sarda*) and wahoo (*Acanthocybium solanderi*).

Catch and effort information for 1981 through 2002 were available. Based on prior MSAP recommendations for the Gulf king stock, trips were restricted as follow: a) fishing trips during the months of July through December, b) for the private/rental, or charter modes, and c) trips with hook and line as fishing gear only. For the Atlantic king stock, trip restrictions included: a) fishing trips during the months of April through December, b) charter and private/rental modes, and c) hook and line fishing gear only. Nominal indices were calculated as total number of fish caught (A+B1+B2) per thousand anglers fishing. In case of interviews where catch came from more than one angler, nominal CPUE was adjusted for non-interviewed anglers who contributed to catch by assuming similar catch to those anglers interviewed in a given trip or intercept. For the Gulf of Mexico king stock, intercepts from July through December were chosen to reduce the influence of trip limit regulations. Figure 1 shows the frequency distributions of log–transformed nominal CPUE of king mackerel successful trips. The explanatory variables considered for the king MRFSS indices analysis included: year; bi-month: Mar-Apr, May-Jun, Jul-Aug, Sep-Oct, Nov-Dec; Fishing mode: private/rental boats, or charter boats; Area: inshore, continental shelf (3 miles or less in the Atlantic coast, Louisiana, Mississippi and Alabama, 10 miles or less in the Florida Gulf coast), and offshore; And fishing target where target 1 specifically included king mackerel as targeted species, target 2 where other migratory coastal species where the main targets.

For the Spanish stocks (Atlantic and Gulf) trip restrictions included: a) fishing trips during March through December, b) charter, private/rental and shore fishing modes, and c) hook and line fishing gear only. Nominal catch rates were calculated as number of fish caught (A+B1+B2) per thousand anglers fishing. Similar to king, nominal catch rates were adjusted for Spanish mackerel if more than one angler contributed to the catch reported. Explanatory factors evaluated included: year, fishing mode, bi-month, area, and fishing target. Figure 2 shows the frequency distributions of log–transformed nominal CPUE of Spanish mackerel successful trips.

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

Texas Parks & Wildlife. The Texas Parks and Wildlife Department Recreational Angler Creel Survey data set includes catch and fishing effort information for both king and Spanish mackerel from 1983 through 2001. CPUE analysis for king mackerel was restricted to the summer months (May – September), the charter and private modes, and the offshore area. Only the major bay classification areas of Matagorda, San Antonio, Port Aransas, Corpus Christi, and lower Laguna Madre were included. Inshore areas and passes were excluded from the present analyses, as king mackerel are rarely caught in these areas. The index was the standardized number of fish per thousand fishing hours. The explanatory variables considered included year, month, major bay, and area (nearshore <10 miles from shoreline, and offshore ≥ 10 miles). Figure 3 shows the frequency distribution of log transformed nominal CPUE for trips with successful king and Spanish mackerel catch in the final dataset. For Spanish mackerel, catch rate analysis was restricted to the months of May to October, the private/rental mode, and fishing trips of 24 hours or less.

Headboat Survey. The headboat survey was described by Dixon and Huntsman (1990). Nominal catch rates were estimated as the number of fish landed per thousand anglers. This survey covered Headboats from Cape Hatteras, North Carolina to the Texas coast in the Gulf of Mexico; geographically the survey considered 26 areas (Figure 4). In the case of king mackerel, all areas were included in the analysis; for Spanish mackerel, only those areas where catch has been reported in any year were included. For both species, data were also restricted to trips of

24 hours or less. Analysis of king mackerel catch by vessel indicated that for the Gulf of Mexico region 284 vessels-ID reported catch from 1981 to 2001. However, of these, 100 vessels accounted for 91% of the total catch as well as having at least 7 or more years of king catch within the 1981-2001 period. Similarly, in the Atlantic 216 different vessel-ID had been reported, with 69 vessels accounting for 89% of the total catch (Fig 5). Thus for the catch rates analysis, for king mackerel, data were also restricted to vessels with 7+ years of reported catch. In the case of Spanish mackerel, data were restricted also to trips of 24 hours or less and vessels that reported Spanish mackerel catch for at least 6 or more years between 1983 and 2001 (Fig 6). Figure 7 shows the frequency distribution of log transformed nominal CPUE for trips with successful king and Spanish mackerel catch in the final data set.

Index Development.

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

A step-wise regression procedure was used to determine the set of systematic factors and interactions that significantly explained the observed variability. The deviance difference between two consecutive model formulations followed a χ^2 (Chi-square) distribution. This statistic was used to test for the significance of an additional factor in the model. The number of additional parameters associated with the added factor minus one corresponded to the number of degrees of freedom in the Chi-square test (McCullagh and Nelder 1989). Deviance analysis tables were presented for all data set analyses; each table included the deviance for the proportion of positive observations, and the deviance for the positive catch rates. Final selection of explanatory factors was conditional on: a) the relative percent of deviance explained by adding the factor in evaluation, normally factors that explained more than 5 to 10% of deviance were selected, b) the Chi-square test significance, and c) the type III test significance within the final specified model. Once a set of fixed factors was specified, possible 1st level interactions were evaluated, in particular random interactions between the year effect and other factors. Analyses were performed using the GLIMMIX and MIXED procedures from the SAS® statistical computer software (SAS Institute Inc. 1997, Littell *et al.* 1996). Once a set of fixed factors and interactions was selected for each species, all interactions that included the factor *year* were assumed as random interactions. This assumption allowed estimation of annual indices, which was the main objective of the standardization process, but also recognized the variability, associated with year factors interactions that were significant. This process converted the base models into Generalized linear mixed models (GLMM) category. The significance of random interactions could be evaluated between nested models by using the likelihood ratio test (Pinheiro and Bates 2000). Similarly, the Akaike information criteria (AIC) and the Schwarz Bayesian information criteria (BIC) could be used to indicate mixed model fit, where smaller values of AIC or BIC indicated best model fit (Littell et al 1996).

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

Results and Discussion
MRFSS dataset.

Deviance analysis tables indicated that target was a main explanatory variable for catch rates of king mackerel in recreational fisheries. In both model components, the proportion of positive to total trips and the mean catch rate of successful trips, the target indicator accounted for a high percent of explained deviance (Table 1). Subsequent to target, area, bi-month and mode were significant factors for king mackerel catch rates. Interaction random terms of year and area and bi-month were significant in the case of king mackerel catch rates of positive observations (Table 2). Table 3 presents the standardized catch rates with 95% confidence intervals, coefficient of variance and number of observations per year in the analyzed data. Overall, coefficients of variance ranged from

46% to 70% for king mackerel Atlantic stock, and from 48% to 64% for king mackerel Gulf stock, respectively. Figure 8 shows the cumulative normalized deviance residuals or qq-plots for the final model of the positive observations fitting for both king mackerel stocks. The qq-plots can be used as a non-formal diagnostic for the fit of the positive trips component in the delta formulations, the expected plot is a straight line of the cumulative residuals (McCullagh and Nelder 1989). Figure 9 shows the standardized CPUE series. For the Gulf king mackerel stock, there was not a clear trend, highest catch rate values corresponded to the 1991/92 and 1997/98 fishing year. In the case of the Atlantic king stock, highest catch rates corresponded to early years, 1982 and 1987, in recent years overall values were about 50 to 60% of the highest catch rates estimated. However, estimates of variance indicated no significant trend in the catch rate for the last 10 years.

For Spanish mackerel, deviance analysis tables show that target was a main explanatory variable (Table 4). Area and mode were also included as explanatory variables for both catch rates and proportion of successful trips. Although bag limits were evaluated in the analysis, the lack of contrast between years for different bag restrictions prevented this factor from being included in the model. For Spanish mackerel, interactions of year*bi-month and year*area were significant particularly for the estimated proportion of positive trips (Table 5). Figure 10 shows the corresponding qq-plots for the Spanish mackerel final models. Table 6 presents the standardized catch rates with 95% confidence intervals, overall coefficients of variance range from 44% to 75% for Spanish Atlantic stock and 46% to 72% for Spanish Gulf stock. There were no distinguishable trends in the standardized series for both Spanish mackerel stocks, in addition to the wide confidence intervals estimated by the models (Fig 11).

Texas Parks & Wildlife Department Recreational Angler Creel Survey.

Table 7 shows the deviance analysis for king and Spanish Gulf mackerel catch rates. The bay, area (near shore and offshore) and month factors were the main explanatory variables. Figure 12 shows the cumulative normalized deviance residuals for the final model of the positive observations fitting for mackerels Gulf stocks. The interactions, particularly of year*bay, explained significant percent of the variability observed for both species. The mixed model analysis indicated that year*month and area*bay interactions were also significant, in particular for king mackerel, reflecting the seasonal character for this species in the recreational fishery off Texas (Table 8). Figure 12 shows the cumulative normalized deviance residuals or qq-plots for the final model of the positive observations fitting for both king and Spanish mackerel stocks. Table 9 and Figure 13 show the standardized catch rates for king mackerel Gulf stock. In recent years, estimated catch rates have been on average bellow the values estimated for the early 1990's for both king and Spanish mackerel.

HeadBoat Survey.

The Headboat index deviance analysis tables indicated the importance of the vessel factor for king and Spanish mackerels in both the Gulf and the Atlantic regions, especially in the estimation of positive trips in the delta model formulations (Table 10). Area was another important explanatory variable for all stocks, as well the interactions of year*vessel and year*area. Because of the relative large number of vessels-IDs, including vessel as a fixed factor was not possible, as the models rapidly run out of degrees of freedom. Therefore, alternative formulations were evaluated for the positive observations model component, where the vessel factor was incorporated as a random factor, either assuming an unstructured covariance matrix (default model), or with alternative covariance matrix structures that reflected the correlation of contiguous samples in time within vessel (AutoRegressive AR1 covariance model) (Littell et al 1996, Ortiz et al 2002). Another covariance structure evaluated was the compound symmetric model (CS), which assumeed a constant variance for each vessel through the series. Table 11 shows the analyses for the different mixed model formulation of headboat survey data. For king mackerel stocks, the CS variance model was selected based on the smallest AIC and BIC criteria, as well the likelihood ratio test. For Spanish mackerel, the interaction of Year*Area, and including vessel both as random factors yield the best model fits according to the criteria measures. Figure 14 shows the cumulative normalized deviance residuals for the final models of the positive observations fitting for mackerels Gulf stocks. Table 12 shows the standardized catch rate series for king and Spanish stocks from the Headboat survey data. For king mackerel coefficients of variance ranged from 7% to 12% for Gulf king and 21% to 29% for Atlantic king (Fig 15). Larger coefficients were estimated for Spanish mackerel stocks; for Gulf Spanish it ranged from 40% to 80%, and for Atlantic Spanish from 34% to 41% (Fig 16).

Comparison of indices of abundance between data sets.

Figure 17 shows the standardized CPUE from the MRFSS, Texas PWD, and the Headboat data sets. All series were scaled to the its respective mean for the common years for king mackerel stocks. In the case of Atlantic king, the series diverged mainly in the earlier years 1982/83. For the Gulf stock, the three series showed general agreement in the latest years, showing overall above average catch rate values. Figure 18 shows the equivalent standardized series for Spanish mackerel stocks. For the Atlantic stock, the series show no clear agreement, particularly for the latest 3 years; with the MRFSS series showing a large drop in catch rates compare to prior years, while the Headboat did not reflect this drop. However, both series indicated an increasing trend in their latest year. For the Spanish Gulf stock, the standardized series showed large variations, particularly prior to 1990. With the exception of the Headboat peak in 1991 and the Texas WPD peak in 1995/96, the series were more stable in the more recent part of the 1990's.

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

KING MACK GULF MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	1840.56			
Year	16	1774.65	65.9	22.7%	< 0.001
Year Area	2	1651.33	123.3	42.5%	< 0.001
Year Area Targ1	1	1617.17	34.2	11.8%	< 0.001
Year Area Targ1 Mode	1	1617.09	0.1	0.0%	0.768
Year Area Targ1 Mode Bymonth	2	1616.09	1.0	0.3%	0.609
Year Area Targ1 Mode Bymonth Year*Targ1	16	1600.66	15.4	5.3%	0.493
Year Area Targ1 Mode Bymonth Year*Mode	16	1594.08	22.0	7.6%	0.143
Year Area Targ1 Mode Bymonth Year*Bymonth	30	1556.04	60.1	20.7%	< 0.001
Year Area Targ1 Mode Bymonth Year*Area	24	1550.06	66.0	22.7%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	2638.89			
year	16	2415.64	223.3	11.3%	< 0.001
year mode	1	1547.03	868.6	44.1%	< 0.001
year mode targ1	1	942.93	604.1	30.7%	< 0.001
year mode targ1 area	2	870.50	72.4	3.7%	< 0.001
year mode targ1 area bymonth	2	816.17	54.3	2.8%	< 0.001
year mode targ1 area bymonth year*targ1	16	757.48	58.7	3.0%	< 0.001
year mode targ1 area bymonth year*area	32	729.42	86.7	4.4%	< 0.001
year mode targ1 area bymonth year*mode	16	701.08	115.1	5.8%	< 0.001
year mode targ1 area bymonth year*bymonth	30	670.90	145.3	7.4%	< 0.001

KING MACK ATLANTIC MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	3549.869			
Year	21	3471.447	78.4	16.4%	< 0.001
Year Area	2	3409.747	61.7	12.9%	< 0.001
Year Area Targ1	1	3269.239	140.5	29.3%	< 0.001
Year Area Targ1 Mode	1	3268.198	1.0	0.2%	0.308
Year Area Targ1 Mode Bymonth	4	3199.767	68.4	14.3%	< 0.001
Year Area Targ1 Mode Bymonth Year*Area	31	3170.008	29.8	6.2%	0.530
Year Area Targ1 Mode Bymonth Year*Targ1	21	3164.901	34.9	7.3%	0.029
Year Area Targ1 Mode Bymonth Year*Mode	21	3160.330	39.4	8.2%	0.009
Year Area Targ1 Mode Bymonth Year*Bymonth	75	3070.693	129.1	26.9%	< 0.001

Model factors proportion of positive / total obs	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	4099.43			
year	21	3931.35	168.1	6.0%	< 0.001
year mode	1	3571.74	359.6	12.9%	< 0.001
year mode targ1	1	1786.34	1785.4	64.3%	< 0.001
year mode targ1 area	2	1593.53	192.8	6.9%	< 0.001
year mode targ1 area bymonth	4	1518.94	74.6	2.7%	< 0.001
year mode targ1 area bymonth year*targ1	21	1468.89	50.1	1.8%	< 0.001
year mode targ1 area bymonth year*mode	21	1437.95	81.0	2.9%	< 0.001
year mode targ1 area bymonth year*area	42	1406.69	112.2	4.0%	< 0.001
year mode targ1 area bymonth Year*Bymonth	78	1321.06	197.9	7.1%	< 0.001

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

King mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Mode Targ1 Bymonth	1659.8	1661.8	1665.9		
Year Mode Targ1 Bymonth *Year*Bymonth*	1615.7	1619.1	1622.8	44.1	0.0000
Year Mode Targ1 Bymonth *Year*Bymonth Year*Mode*	1563.4	1569.4	1575.1	52.3	0.0000
Positive Catch					
Year Area Targ1 Bymonth	4888.7	4890.7	4896.1		
Year Area Targ1 Bymonth *Year*Area*	4862.8	4866.8	4870.4	25.9	0.0000
Year Area Targ1 Bymonth *Year*Area Year*Bymonth*	4852.1	4858.1	4863.4	10.7	0.0011

King mackerel Atlantic Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Targ1 Mode Area Bymonth	2824.6	2826.6	2831.2		
Year Targ1 Mode Area Bymonth *Year*Bymonth*	2818.3	2822.3	2827.6	6.3	0.0121
Year Targ1 Mode Area Bymonth *Year*Bymonth Year*Area*	2811.1	2817.1	2825	7.2	0.0073
Positive Catch					
Year Targ1 Area Bymonth Mode	10181.5	10183.5	10189.7		
Year Targ1 Area Bymonth Mode *Year*Bymonth*	10157.9	10161.9	10167.1	23.6	0.0000
Year Targ1 Area Bymonth Mode *Year*Bymonth Year*Mode*	10149.9	10155.9	10163.8	8	0.0047

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

King Atlantic stock

Year	N obs	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1981	100	48.722	45.244	69.0%	0.363	1.264	0.104
1982	145	95.861	119.827	61.1%	0.962	2.966	0.312
1983	161	114.964	82.246	57.8%	0.660	1.933	0.225
1984	136	64.727	46.753	63.0%	0.375	1.192	0.118
1985	90	74.511	41.854	69.4%	0.336	1.177	0.096
1986	383	80.996	34.842	57.3%	0.280	0.812	0.096
1987	784	119.750	124.624	49.9%	1.000	2.567	0.389
1988	1013	55.770	44.156	50.0%	0.354	0.911	0.138
1989	1017	43.339	34.823	50.9%	0.279	0.730	0.107
1990	1163	66.172	68.628	48.2%	0.551	1.373	0.221
1991	1249	62.244	44.015	48.5%	0.353	0.886	0.141
1992	1285	54.779	42.649	48.3%	0.342	0.855	0.137
1993	907	48.031	21.689	53.6%	0.174	0.476	0.064
1994	1167	28.624	24.247	53.7%	0.195	0.532	0.071
1995	992	48.407	35.394	52.5%	0.284	0.762	0.106
1996	1073	50.293	24.878	50.5%	0.200	0.518	0.077
1997	1217	65.409	53.795	49.2%	0.432	1.095	0.170
1998	1199	45.481	38.355	49.7%	0.308	0.788	0.120
1999	1524	56.061	35.036	47.1%	0.281	0.688	0.115
2000	1472	64.300	55.291	46.2%	0.444	1.068	0.184
2001	1388	47.521	18.258	47.5%	0.147	0.361	0.059
2002	1470	47.502	29.440	46.3%	0.236	0.571	0.098

King Gulf stock

Year	N obs	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1986	465	26.282	31.749	63.1%	0.243	0.774	0.076
1987	395	84.563	71.095	56.4%	0.545	1.557	0.190
1988	298	69.304	64.241	54.4%	0.492	1.363	0.178
1989	238	60.401	44.694	57.4%	0.342	0.995	0.118
1990	162	95.019	122.529	55.4%	0.938	2.641	0.334
1991	196	158.137	130.559	50.2%	1.000	2.580	0.388
1992	281	125.513	99.915	52.3%	0.765	2.048	0.286
1993	307	61.318	67.737	49.5%	0.519	1.322	0.204
1994	246	86.157	65.302	55.7%	0.500	1.414	0.177
1995	155	50.719	56.185	63.5%	0.430	1.379	0.134
1996	262	59.442	95.417	54.3%	0.731	2.021	0.264
1997	452	140.676	107.086	50.1%	0.820	2.114	0.318
1998	769	63.225	64.847	50.9%	0.497	1.297	0.190
1999	750	103.861	72.518	49.6%	0.555	1.420	0.217
2000	827	129.506	84.651	46.6%	0.648	1.573	0.267
2001	783	81.981	65.264	50.1%	0.500	1.288	0.194
2002	301	88.747	56.182	62.7%	0.430	1.360	0.136

Table 4. Analysis of deviance for the mean catch rate of successful observations and the proportion of positive to total observations for Spanish mackerel from the MRFSS CPUE data. *p* value refers to the Chi-square probability test between two consecutive model formulations

SPANISH MACK GULF MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	7587.54			
Year	18	7120.66	466.9	21.1%	< 0.001
Year Target	1	5818.21	1302.4	58.9%	< 0.001
Year Target Area	2	5721.55	96.7	4.4%	< 0.001
Year Target Area Mode	2	5649.46	72.1	3.3%	< 0.001
Year Target Area Mode Baglimt	0	5585.11	64.3	2.9%	#NUM!
Year Target Area Mode Baglimt Bymonth	4	5585.11	0.0	0.0%	1.000
Year Target Area Mode Baglimt Bymonth Year*Area	34	5505.17	79.9	3.6%	< 0.001
Year Target Area Mode Baglimt Bymonth Year*Target	18	5459.34	125.8	5.7%	< 0.001
Year Target Area Mode Baglimt Bymonth Year*Mode	36	5441.40	143.7	6.5%	< 0.001
Year Target Area Mode Baglimt Bymonth Year*Bymonth	70	5377.76	207.4	9.4%	< 0.001

Model factors proportion of positive to total	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	10911.71			
Year	18	10595.98	315.7	3.2%	< 0.001
Year Target	1	1937.28	8658.7	88.9%	< 0.001
Year Target Area	2	1418.12	519.2	5.3%	< 0.001
Year Target Area Mode	2	1401.28	16.8	0.2%	< 0.001
Year Target Area Mode Bymonth	4	1343.63	57.7	0.6%	< 0.001
Year Target Area Mode Bymonth Year*Target	18	1277.65	66.0	0.7%	< 0.001
Year Target Area Mode Bymonth Year*Target Year*Mode	36	1246.73	30.9	0.3%	0.709
Year Target Area Mode Bymonth Year*Target Year*Area	35	1197.93	79.7	0.8%	< 0.001
Year Target Area Mode Bymonth Year*Target Year*Bymonth	70	1171.16	106.5	1.1%	0.003

SPANISH MACK ATLANTIC MRFSS

Model factors positive catch rates values	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	8628.50			
Year	21	8450.10	178.4	10.0%	< 0.001
Year Target	1	7579.32	870.8	48.9%	< 0.001
Year Target Area	2	7446.11	133.2	7.5%	< 0.001
Year Target Area Mode	2	7117.56	328.6	18.5%	< 0.001
Year Target Area Mode Bymonth	4	7103.49	14.1	0.8%	0.007
Year Target Area Mode Bymonth Year*Target	21	7052.43	51.1	2.9%	< 0.001
Year Target Area Mode Bymonth Year*Area	39	7049.61	53.9	3.0%	0.057
Year Target Area Mode Bymonth Year*Mode	41	6986.79	116.7	6.6%	< 0.001
Year Target Area Mode Bymonth Year*Bymonth	81	6849.02	254.5	14.3%	< 0.001

Model factors proportion of positive to total	degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	18869.40			
Year	21	17999.35	870.1	5.0%	< 0.001
Year Target	1	1660.07	16339.3	93.0%	< 0.001
Year Target Area	2	1638.08	22.0	0.1%	< 0.001
Year Target Area Mode	2	1635.91	2.2	0.0%	0.339
Year Target Area Mode Bymonth	4	1489.18	146.7	0.8%	< 0.001
Year Target Area Mode Bymonth Year*Mode	42	1410.67	78.5	0.4%	< 0.001
Year Target Area Mode Bymonth Year*Area	41	1380.32	108.9	0.6%	< 0.001
Year Target Area Mode Bymonth Year*Target	21	1346.00	143.2	0.8%	< 0.001
Year Target Area Mode Bymonth Year*Bymonth	82	1296.78	192.4	1.1%	< 0.001

Table 5. Analysis of delta lognormal mixed model formulations for king and Spanish mackerel catch rates from the MRFSS data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models. Italics represent the random interactions evaluated.

Spanish mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Target Mode Area	4140.4	4142.4	4147.3		
Year Target Mode Area *Year*Area*	4021.9	4025.9	4030	118.5	0.0000
Year Target Mode Area *Year*Area Year*Bymonth*	3953	3959	3965.1	68.9	0.0000
Positive Catch					
Year Target Area Mode Bymonth	15004.4	15006.4	15013		
Year Target Area Mode Bymonth *Year*Target*	14934.1	14938.1	14941.3	70.3	0.0000
Year Target Area Mode Bymonth *Year*Target Year*Mode*	14915.3	14921.3	14926.3	18.8	0.0000
Year Target Area Mode Bymonth *Year*Target Year*Mode Year*Bymonth*	14888	14896	14902.6	46.1	0.0000

Spanish mackerel Atlantic Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Target Area Bymonth	4665.8	4667.8	4672.8		
Year Target Area Bymonth *Year*Target*	4576.2	4580.2	4583.7	89.6	0.0000
Year Target Area Bymonth *Year*Target Year*Bymonth*	4555.6	4561.6	4566.9	20.6	0.0000
Year Target Area Bymonth *Year*Target Year*Bymonth Year*Area*	4501.1	4509.1	4516.2	54.5	0.0000
Positive Catch					
Year Target Area Mode Bymonth	18392.4	18394.4	18401.1		
Year Target Area Mode Bymonth *Year*Mode*	18373.1	18377.1	18381.5	19.3	0.0000
Year Target Area Mode Bymonth *Year*Mode Year*Bymonth*	18345.7	18351.7	18358.2	27.4	0.0000

Table 6. Spanish mackerel standardized catch rate, 95% confidence intervals and coefficient of variation from the MRFSS dataset. Index represents the scaled standard CPUE (fish/1000 hours) to the maximum value of the series.

Spanish Atlantic stock

Year	N obs	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1981	131	337.024	385.314	67.0%	0.819	2.770	0.242
1982	214	225.987	335.577	72.2%	0.714	2.606	0.195
1983	211	21.730	137.468	75.8%	0.292	1.124	0.076
1984	207	46.877	161.162	67.7%	0.343	1.170	0.100
1985	119	304.283	334.869	70.2%	0.712	2.524	0.201
1986	516	111.442	216.703	66.2%	0.461	1.538	0.138
1987	903	398.821	432.377	49.3%	0.919	2.338	0.362
1988	1214	303.429	234.303	52.6%	0.498	1.338	0.185
1989	1258	296.616	470.299	48.6%	1.000	2.513	0.398
1990	1366	356.845	363.159	45.5%	0.772	1.838	0.324
1991	1646	336.363	263.034	44.5%	0.559	1.310	0.239
1992	1679	250.973	353.111	45.8%	0.751	1.797	0.314
1993	1205	220.354	167.872	52.8%	0.357	0.962	0.132
1994	1485	388.739	154.968	46.6%	0.330	0.800	0.136
1995	1407	229.994	358.088	53.5%	0.761	2.076	0.279
1996	1429	210.185	289.923	48.9%	0.616	1.557	0.244
1997	1489	273.338	364.519	51.0%	0.775	2.028	0.296
1998	1712	141.517	277.459	50.1%	0.590	1.519	0.229
1999	1715	207.132	377.402	46.4%	0.802	1.942	0.332
2000	1744	237.327	228.848	47.6%	0.487	1.202	0.197
2001	1839	181.641	103.440	52.0%	0.220	0.585	0.083
2002	1450	167.314	325.687	57.0%	0.693	2.002	0.240

Spanish Gulf stock.

Year	N obs	Nominal	Standardized	Coeff Var	Index	95% confidence intervals	
1984	68	119.118	167.365	74.4%	0.232	0.877	0.062
1985	84	335.027	147.855	64.3%	0.205	0.666	0.063
1986	615	800.750	548.412	51.8%	0.762	2.021	0.287
1987	775	237.091	238.526	52.1%	0.331	0.883	0.124
1988	504	420.470	605.099	54.5%	0.840	2.330	0.303
1989	356	377.361	720.047	53.2%	1.000	2.713	0.369
1990	304	1120.636	313.915	54.0%	0.436	1.200	0.158
1991	373	526.102	626.124	50.9%	0.870	2.270	0.333
1992	679	484.565	445.528	50.5%	0.619	1.605	0.239
1993	640	706.729	324.377	52.4%	0.450	1.206	0.168
1994	684	341.462	337.054	51.0%	0.468	1.224	0.179
1995	316	461.928	178.957	60.5%	0.249	0.759	0.081
1996	552	484.923	408.150	51.0%	0.567	1.483	0.217
1997	694	342.038	139.638	55.5%	0.194	0.547	0.069
1998	1072	343.126	431.306	49.2%	0.599	1.520	0.236
1999	1358	324.107	332.567	47.2%	0.462	1.133	0.188
2000	1741	185.950	240.485	48.5%	0.334	0.837	0.133
2001	1455	375.658	373.888	46.8%	0.519	1.265	0.213
2002	1111	323.494	314.899	50.7%	0.437	1.137	0.168

Table 7. Analysis of deviance for the mean catch rate of successful observations and the proportion of positive to total observations for king and Spanish mackerel from the Texas Parks and Wildlife Division Recreational Angler Creel Survey data. *p* value refers to the Chi-square probability test between two consecutive model formulations.

GULF MEXICO KING MACKEREL

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	2631.0			
Year	18	2562.8	68.3	17.3%	< 0.001
Year Mode	1	2551.7	11.1	2.8%	< 0.001
Year Mode Area	1	2522.8	28.9	7.3%	< 0.001
Year Mode Area Bay	4	2503.1	19.8	5.0%	< 0.001
Year Mode Area Bay Month	4	2482.0	21.1	5.4%	< 0.001
Year Mode Area Bay Month Year:Mode	18	2456.9	25.1	6.4%	0.123
Year Mode Area Bay Month Year:Mode Year:Area	18	2445.0	11.9	3.0%	0.854
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area	1	2445.0	0.1	0.0%	0.783
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay	72	2345.1	99.8	25.4%	0.017
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay	4	2341.3	3.9	1.0%	0.425
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay	4	2327.6	13.7	3.5%	0.008
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month	68	2270.2	57.4	14.6%	0.818
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month Mode:Month	4	2260.0	10.2	2.6%	0.037
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month Mode:Month Area:Month	4	2247.0	13.0	3.3%	0.012
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month Mode:Month Area:Month Bay:Month	16	2237.4	9.7	2.5%	0.883

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	13254.5			
Year	18	13070.6	183.91	11.5%	< 0.001
Year Mode	1	12942.1	128.52	8.1%	< 0.001
Year Mode Area	1	12860.3	81.79	5.1%	< 0.001
Year Mode Area Bay	4	12619.8	240.53	15.1%	< 0.001
Year Mode Area Bay Month	4	12377.0	242.77	15.2%	< 0.001
Year Mode Area Bay Month Year:Mode	18	12337.2	39.81	2.5%	0.002
Year Mode Area Bay Month Year:Mode Year:Area	18	12299.7	37.43	2.3%	0.005
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area	1	12298.1	1.60	0.1%	0.206
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay	72	12065.5	232.61	14.6%	< 0.001
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay	4	12054.4	11.10	0.7%	0.025
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay	4	11938.7	115.74	7.3%	< 0.001
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month	70	11726.7	212.02	13.3%	< 0.001
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month Mode:Month	4	11723.1	3.57	0.2%	0.467
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month Mode:Month Area:Month	4	11719.4	3.67	0.2%	0.453
Year Mode Area Bay Month Year:Mode Year:Area Mode:Area Year:Bay Mode:Bay Area:Bay Year:Month Mode:Month Area:Month Bay:Month	16	11659.1	60.35	3.8%	< 0.001

GULF SPANISH MACKEREL

Model factors positive catch rates values	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	1516.6			
Year	18	1463.1	53.4	12.0%	< 0.001
Year Area	2	1393.8	69.3	15.6%	< 0.001
Year Area Bay	4	1372.6	21.3	4.8%	< 0.001
Year Area Bay Month	5	1350.9	21.7	4.9%	< 0.001
Year Area Bay Month Year:Area	36	1321.2	29.8	6.7%	0.759
Year Area Bay Month Year:Area Year:Bay	68	1192.7	128.5	28.8%	< 0.001
Year Area Bay Month Year:Area Year:Bay Year:Month	84	1110.5	82.2	18.4%	0.536
Year Area Bay Month Year:Area Year:Bay Year:Month Area:Month	10	1095.5	15.1	3.4%	0.130
Year Area Bay Month Year:Area Year:Bay Year:Month Area:Month Area:Bay	8	1092.1	3.3	0.7%	0.912
Year Area Bay Month Year:Area Year:Bay Year:Month Area:Month Area:Bay Bay:Month	20	1071.2	21.0	4.7%	0.398

Model factors proportion positives	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	17641.4			
Year	18	17448.8	192.56	6.1%	< 0.001
Year Area	2	15918.3	1530.48	48.5%	< 0.001
Year Area Bay	4	15493.4	424.89	13.5%	< 0.001
Year Area Bay Month	5	15184.3	309.15	9.8%	< 0.001
Year Area Bay Month Year:Area	36	15094.6	89.68	2.8%	< 0.001
Year Area Bay Month Year:Bay	68	14915.3	179.30	5.7%	< 0.001
Year Area Bay Month Year:Month	90	14488.1	427.21	13.5%	< 0.001

Table 8. Analysis of delta lognormal mixed model formulations for king mackerel catch rates from the TPWD recreational angler creel survey data. Likelihood ratio tests the difference of –2 REM log likelihood between two nested models

King mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Mode Area Bay Month	3805.3	3807.3	3812.2		
Year Mode Area Bay Month *Year*Month*	3783.8	3787.8	3792.9	21.5	0.0000
Year Mode Area Bay Month *Year*Month Year*Bay*	3778.4	3784.4	3792	5.4	0.0201
Year Mode Area Bay Month *Year*Month Year*Bay Area*Bay*	3747.5	3755.5	3765.7	30.9	0.0000
Positive Catch					
Year Area Bay Month Mode	9033.6	9035.6	9041.8		
Year Area Bay Month Mode *Year*Bay*	9010.8	9014.8	9019.9	22.8	0.0000
Year Area Bay Month Mode *Year*Bay Year*Mode*	9003.4	9009.4	9017	7.4	0.0065

Spanish mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Bay Area Month	6105.4	6107.4	6112.6		
Year Bay Area Month *Year*Bay*	6038.6	6042.6	6047.6	66.8	0.0000
Year Bay Area Month *Year*Bay Year*Month*	5959.6	5965.6	5973.2	79	0.0000
Positive Catch					
Year Bay Area Month	4700	4702	4707.5		
Year Bay Area Month *Year*Bay*	4652.1	4656.1	4661.1	47.9	0.0000
Year Bay Area Month *Year*Bay Year*Month*	4628.8	4634.8	4642.3	23.3	0.0000

Table 9. King and Spanish mackerel standardized catch rates, 95% confidence intervals and coefficient of variance from the TPWD Recreational Angler Creel Survey data.

King Gulf stock.

Year	N Obs	Nominal	Standardized	CV	Index	95% CI	
1983	616	80.808	63.004	28.7%	0.836	1.467	0.476
1984	1020	74.137	62.461	28.8%	0.828	1.458	0.471
1985	766	75.243	52.282	29.4%	0.693	1.234	0.390
1986	514	33.070	23.262	33.3%	0.309	0.590	0.161
1987	524	47.965	44.616	30.4%	0.592	1.072	0.326
1988	437	48.579	35.581	30.7%	0.472	0.860	0.259
1989	357	53.742	37.946	32.0%	0.503	0.940	0.269
1990	481	35.302	30.409	32.2%	0.403	0.755	0.215
1991	421	78.235	75.402	28.9%	1.000	1.761	0.568
1992	390	61.991	53.288	31.0%	0.707	1.295	0.386
1993	411	62.608	48.908	31.9%	0.649	1.208	0.348
1994	355	66.936	49.220	31.1%	0.653	1.199	0.355
1995	494	63.586	52.237	30.6%	0.693	1.260	0.381
1996	484	73.359	60.461	29.5%	0.802	1.429	0.450
1997	501	72.179	43.297	32.7%	0.574	1.086	0.304
1998	723	76.239	56.686	31.2%	0.752	1.383	0.409
1999	614	66.995	46.781	32.8%	0.620	1.176	0.327
2000	730	43.122	34.855	33.3%	0.462	0.884	0.242
2001	335	56.708	27.627	37.9%	0.366	0.763	0.176

Spanish Gulf stock.

Year	N Obs	Nominal	Standardized	CV	Index	95% CI	
1983	3241	3.961	5.845	36.0%	1.000	2.009	0.498
1984	3290	1.124	1.635	43.2%	0.280	0.640	0.122
1985	3682	2.847	3.444	36.9%	0.589	1.203	0.289
1986	3508	0.815	1.079	47.0%	0.185	0.451	0.075
1987	4802	7.332	3.646	35.8%	0.624	1.248	0.312
1988	4487	1.366	1.589	40.0%	0.272	0.588	0.126
1989	3658	4.572	3.274	39.1%	0.560	1.190	0.264
1990	3448	4.073	2.613	37.6%	0.447	0.925	0.216
1991	4184	5.319	4.415	34.7%	0.755	1.484	0.384
1992	4489	2.014	2.776	36.4%	0.475	0.962	0.234
1993	5221	2.399	2.760	35.6%	0.472	0.943	0.237
1994	5471	3.373	3.008	34.9%	0.515	1.015	0.261
1995	5196	4.603	4.641	33.4%	0.794	1.520	0.415
1996	4942	6.123	5.235	33.4%	0.896	1.717	0.467
1997	5446	3.343	2.931	35.2%	0.501	0.993	0.253
1998	5551	3.124	2.041	38.0%	0.349	0.727	0.168
1999	6148	2.017	1.967	36.9%	0.337	0.688	0.165
2000	5933	5.739	2.917	36.2%	0.499	1.007	0.247
2001	5645	2.233	1.871	40.3%	0.320	0.696	0.147

Table 10. Analysis of deviance for the mean catch rate of successful observations and the proportion of positive to total observations for king and Spanish mackerel from the Headboat Survey data. *p* value refers to the Chi-square probability test between two consecutive model formulations.

ATLANTIC KING MACKEREL

Model factors positive catch rates values	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	_	62143.4			
Year	20	61429.2	714.2	3.4%	< 0.001
Year Area	12	48260.1	13169.0	62.2%	< 0.001
Year Area Season	3	47297.2	962.9	4.5%	< 0.001
Year Area Season Vessel	97	41629.5	5667.7	26.8%	< 0.001
Year Area Season Vessel Area*Season	29	41396.6	232.9	1.1%	< 0.001
Year Area Season Vessel Year*Season	58	40976.9	652.6	3.1%	< 0.001
Year Area Season Vessel Year*Area	190	40970.4	659.1	3.1%	< 0.001

Model factors proportion positives	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	77677.0			
Year	20	73006.9	4670.11	7.1%	< 0.001
Year Area	12	28255.8	44751.12	68.3%	< 0.001
Year Area Season	3	27469.4	786.40	1.2%	< 0.001
Year Area Season Vessel	97	15461.3	12008.12	18.3%	< 0.001
Year Area Season Vessel Year*Season	59	14835.0	626.28	1.0%	< 0.001
Year Area Season Vessel Area*Season	30	14583.4	877.84	1.3%	< 0.001
Year Area Season Vessel Year*Area	200	12168.6	3292.65	5.0%	< 0.001

GULF MEXICO KING MACKEREL

Model factors positive catch rates values	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	68115.6			
Year	20	67232.5	883.1	3.4%	< 0.001
Year Area	10	54568.6	12663.9	49.1%	< 0.001
Year Area Month	11	53865.6	703.0	2.7%	< 0.001
Year Area Month Vessel	107	46857.3	7008.3	27.2%	< 0.001
Year Area Month Vessel Baglimt	1	46848.3	9.1	0.0%	0.003
Year Area Month Vessel Baglimt Year*Month	182	45581.0	1267.2	4.9%	< 0.001
Year Area Month Vessel Baglimt Year*Area	161	45445.1	1403.1	5.4%	< 0.001
Year Area Month Vessel Baglimt Year*Vessel	1083	42316.4	4531.8	17.6%	< 0.001

Model factors proportion positives	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	52907.6			
Year	20	50173.1	2734.49	6.1%	< 0.001
Year Area	10	23520.7	26652.40	59.6%	< 0.001
Year Area Month	11	11635.9	11884.80	26.6%	< 0.001
Year Area Month Year*Area	168	8862.5	2773.39	6.2%	< 0.001
Year Area Month Year*Month	182	8208.8	3427.07	7.7%	< 0.001

ATLANTIC SPANISH MACKEREL

Model factors positive catch rates values	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	4971.4			
Year	18	4642.5	328.9	10.5%	< 0.001
Year Area	2	4350.2	292.3	9.3%	< 0.001
Year Area Season	3	4310.7	39.5	1.3%	< 0.001
Year Area Season Vessel	60	2388.8	1921.9	61.2%	< 0.001
Year Area Season Vessel Year*Season	53	2312.4	76.4	2.4%	0.019
Year Area Season Vessel Year*Area	36	2267.8	121.1	3.9%	< 0.001
Year Area Season Vessel Year*Vessel	390	1831.9	556.9	17.7%	< 0.001

Model factors proportion positives	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	7225.2			
Year	18	6919.0	306.21	6.1%	< 0.001
Year Area	2	6857.6	61.42	1.2%	< 0.001
Year Area Season	3	6500.8	356.83	7.1%	< 0.001
Year Area Season Vessel	60	4275.3	2225.45	44.5%	< 0.001
Year Area Season Vessel Year*Season	53	4032.4	242.93	4.9%	< 0.001
Year Area Season Vessel Year*Area	36	4008.8	266.51	5.3%	< 0.001
Year Area Season Vessel Year*Vessel	658	2223.8	2051.56	41.0%	< 0.001

GULF SPANISH MACKEREL

Model factors positive catch rates values	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	3470.8			
Year	18	3374.3	96.5	4.5%	< 0.001
Year Area	4	2375.3	999.0	47.1%	< 0.001
Year Area Season	3	2346.4	29.0	1.4%	< 0.001
Year Area Season Vessel	78	1898.7	447.7	21.1%	< 0.001
Year Area Season Vessel Year*Season	51	1824.6	74.1	3.5%	0.019
Year Area Season Vessel Year*Area	62	1768.7	129.9	6.1%	< 0.001
Year Area Season Vessel Year*Vessel	492	1349.5	549.2	25.9%	0.038

Model factors proportion positives	Degrees of freedom	Residual deviance	Change in deviance	% of total deviance	*p*
1	1	8503.2			
Year	18	8175.1	328.12	5.8%	< 0.001
Year Area	4	7633.1	542.04	9.5%	< 0.001
Year Area Season	3	7305.0	328.13	5.8%	< 0.001
Year Area Season Vessel	79	5305.4	1999.56	35.1%	< 0.001
Year Area Season Vessel Year*Season	53	4997.1	308.31	5.4%	< 0.001
Year Area Season Vessel Year*Area	64	4707.5	597.87	10.5%	< 0.001
Year Area Season Vessel Year*Vessel	803	2802.4	2503.03	43.9%	< 0.001

Table 11. Analysis of delta lognormal mixed model formulations for king and Spanish mackerel catch rates from the Headboat Survey data.

King mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Month	38173.7	38175.7	38182.8		
Year Area Month *Year*Month*	38229.8	38233.8	38240.5	-56.1	N/A
Year Area Month *Year*Month Year*Area*	38197.7	38203.7	38213.8	32.1	0.0000
Positive Catch					
Year Month Area Vessel(AR 1)	126699.1	126703.1	126716.2		
Year Month Area Vessel(CS)	124081.4	124085.4	124098.5	2617.7	0.0000
Year Month Area *Year*Area*	130960.8	130964.8	130971.3	-6879.4	N/A

King mackerel Atlantic Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Season	15783.5	15785.5	15791.7		
Year Area Season *Year*Area*	15629.9	15633.9	15640.8	153.6	0.0000
Year Area Season *Year*Area Year*season*	15619.8	15625.8	15636.1	10.1	0.0015
Year Area Season *Year*Area Year*season Vessel*	14696.2	14704.2	14718	923.6	0.0000
Positive Catch					
Year Area Season *Vessel* [AR1]	130895.1	130899.1	130910.8		
Year Area Season *Vessel* [CS]	130136.9	130140.9	130152.6	758.2	0.0000
Year Area Season *Year*Area Vessel*	130879.8	130885.5	130896.1	-742.9	N/A

Spanish mackerel Gulf Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Season	14178.5	14180.5	14186.5		
Year Area Season *Year*Area*	13982.7	13986.7	13991.6	195.8	0.0000
Year Area Season *Year*Area Year*Season*	13906.9	13912.9	13920.3	75.8	0.0000
Year Area Season *Year*Area Year*Season Year*Vessel*	12930.3	12938.3	12948.2	976.6	0.0000
Positive Catch					
Year Month Area Vessel	7704.9	7706.9	7711.8		
Year Month Area Vessel(AR 1)	7296.7	7300.7	7310.5	408.2	0.0000
Year Month Area Vessel(CS)	7289	7293	7302.9	7.7	0.0055
Year Month Area *Year*Area*	7305.7	7309.7	7314.5	-16.7	N/A
Year Month Area *Year*Area Vessel*	7265.3	7271.3	7278.7	40.4	0.0000

Spanish mackerel Atlantic Model	-2 REM Log likelihood	Akaike's Information Criterion	Schwartz's Bayesian Criterion	Likelihood Ratio Test	
Proportion Positives					
Year Area Season	10893.9	10895.9	10901.7		
Year Area Season *Year*Area*	10784	10788	10792.1	109.9	0.0000
Year Area Season *Year*Area Year*season*	10757	10763	10769.2	27	0.0000
Year Area Season *Year*Area Year*season Vessel*	10224.8	10232.8	10241	532.2	0.0000
Positive Catch					
Year Area Season *Vessel* [AR1]	8923.7	8927.7	8937.4		
Year Area Season *Vessel* [CS]	8743.2	8747.2	8756.9	180.5	0.0000
Year Area Season *Year*Area*	10052	10054	10058.8	-1308.8	N/A
Year Area Season *Year*Area (Vessel)*	8563.6	8567.6	8571.8	1488.4	0.0000

Table 12. King mackerel standardized catch rates, 95% confidence intervals and coefficient of variance from the Headboat Survey data.

King Gulf stock

Year	N Obs	Nominal	Standardized	cv	Index	95% CI	
1981	2880	180.969	393.750	11.5%	0.601	0.755	0.478
1982	2749	90.303	262.039	11.9%	0.400	0.507	0.315
1983	2925	235.937	655.479	10.3%	1.000	1.228	0.814
1984	3125	59.646	182.750	11.9%	0.279	0.353	0.220
1985	4073	67.896	193.631	11.0%	0.295	0.368	0.237
1986	6891	107.672	285.979	8.5%	0.436	0.517	0.368
1987	7055	55.690	137.402	10.5%	0.210	0.258	0.170
1988	7308	48.484	152.119	9.9%	0.232	0.283	0.191
1989	8805	85.306	286.130	8.6%	0.437	0.518	0.368
1990	9372	76.097	260.982	8.8%	0.398	0.475	0.334
1991	9302	105.246	396.573	8.1%	0.605	0.711	0.515
1992	10161	119.291	442.071	7.4%	0.674	0.783	0.581
1993	10415	119.317	477.504	7.3%	0.728	0.842	0.630
1994	10477	117.544	503.340	7.1%	0.768	0.884	0.667
1995	8850	125.853	450.472	7.6%	0.687	0.801	0.590
1996	8606	124.663	594.336	7.5%	0.907	1.053	0.780
1997	8614	153.175	620.412	7.4%	0.947	1.097	0.817
1998	7194	100.143	475.851	8.0%	0.726	0.852	0.618
1999	6022	120.221	592.221	8.1%	0.903	1.061	0.769
2000	5390	104.303	422.012	8.5%	0.644	0.763	0.543
2001	2403	208.375	410.644	11.2%	0.626	0.783	0.501

King Atlantic stock

Year	N Obs	Nominal	Standardized	cv	Index	95% CI	
1981	5510	118.746	91.498	28.5%	0.432	0.757	0.247
1982	6232	89.484	58.742	28.5%	0.278	0.485	0.159
1983	7039	110.102	95.127	26.5%	0.450	0.756	0.267
1984	6454	115.300	108.327	24.8%	0.512	0.835	0.314
1985	7148	86.597	70.348	26.5%	0.332	0.559	0.198
1986	9837	82.940	83.981	24.5%	0.397	0.643	0.245
1987	9690	86.895	114.916	23.0%	0.543	0.855	0.345
1988	8804	64.056	70.087	26.3%	0.331	0.556	0.197
1989	8259	70.809	92.610	25.8%	0.438	0.727	0.263
1990	10291	63.169	103.767	25.2%	0.490	0.805	0.299
1991	9550	110.168	211.592	21.9%	1.000	1.542	0.648
1992	12126	72.657	158.969	22.1%	0.751	1.163	0.485
1993	11074	65.681	108.528	24.0%	0.513	0.824	0.319
1994	10132	66.318	112.896	23.7%	0.534	0.852	0.334
1995	8960	61.086	115.262	23.5%	0.545	0.866	0.343
1996	6860	46.871	82.606	25.7%	0.390	0.647	0.236
1997	7036	64.546	107.377	24.6%	0.507	0.824	0.313
1998	6232	50.579	102.904	25.0%	0.486	0.796	0.297
1999	5209	33.779	113.081	25.0%	0.534	0.874	0.327
2000	5035	67.091	143.679	23.9%	0.679	1.087	0.424
2001	4373	50.930	109.433	25.6%	0.517	0.856	0.312

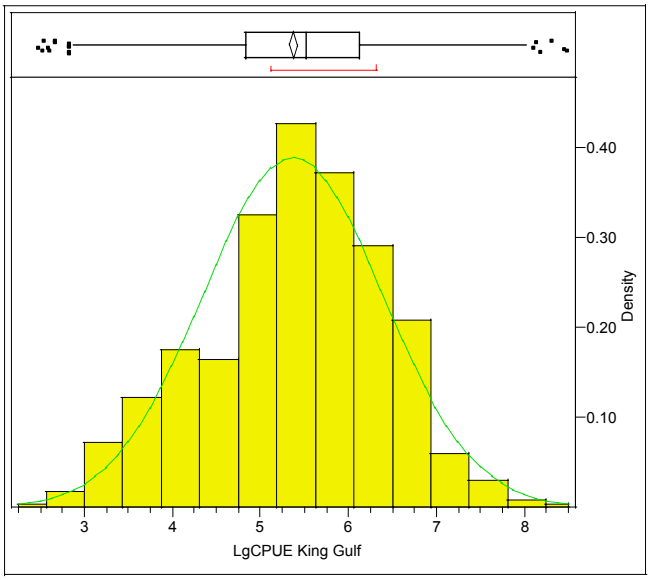
Table 13. Spanish mackerel standardized catch rates, 95% confidence intervals and coefficient of variance from the Headboat Survey data.

Spanish Gulf stock

Year	N Obs	Nominal	Standardized	cv	Index	95% CI	
1983	1658	1.495	5.373	79.7%	0.368	1.497	0.091
1984	1829	1.135	2.748	82.0%	0.188	0.791	0.045
1985	1938	0.492	1.055	71.0%	0.072	0.260	0.020
1986	5333	3.390	4.529	41.6%	0.310	0.690	0.140
1987	4987	7.389	8.626	40.5%	0.591	1.288	0.271
1988	5623	1.836	2.284	45.0%	0.157	0.370	0.066
1989	6864	3.920	5.568	42.5%	0.382	0.862	0.169
1990	9295	3.122	4.509	42.3%	0.309	0.695	0.137
1991	8079	12.895	14.589	39.0%	1.000	2.124	0.471
1992	10179	4.526	5.315	40.4%	0.364	0.793	0.167
1993	9549	2.345	3.225	42.0%	0.221	0.495	0.099
1994	9433	4.501	5.559	40.3%	0.381	0.828	0.175
1995	7858	6.174	5.305	41.1%	0.364	0.801	0.165
1996	8513	4.213	5.561	41.2%	0.381	0.842	0.173
1997	7323	4.015	3.564	42.6%	0.244	0.553	0.108
1998	6752	3.750	3.141	44.1%	0.215	0.501	0.093
1999	5910	2.238	4.316	43.0%	0.296	0.674	0.130
2000	5091	2.169	4.201	43.4%	0.288	0.660	0.126
2001	3909	1.808	3.081	48.7%	0.211	0.531	0.084

Spanish Atlantic stock

Year	N Obs	Nominal	Standardized	cv	Index	95% CI	
1983	8308	3.364	4.176	40.8%	0.490	1.074	0.224
1984	7898	3.481	3.537	40.5%	0.415	0.905	0.190
1985	8318	1.707	3.397	37.3%	0.399	0.821	0.194
1986	10413	7.539	7.227	34.5%	0.848	1.658	0.434
1987	9543	6.010	5.213	36.6%	0.612	1.243	0.301
1988	8733	2.046	2.685	39.3%	0.315	0.673	0.148
1989	8389	2.508	5.164	36.7%	0.606	1.233	0.298
1990	8880	3.195	5.453	36.3%	0.640	1.293	0.317
1991	8648	10.565	7.871	35.0%	0.924	1.825	0.468
1992	10089	6.287	4.329	34.5%	0.508	0.994	0.260
1993	9200	5.195	3.472	35.5%	0.408	0.811	0.205
1994	8297	10.920	5.364	34.6%	0.630	1.234	0.321
1995	7208	2.411	2.193	38.9%	0.257	0.546	0.121
1996	4621	18.876	4.040	37.8%	0.474	0.985	0.228
1997	5781	12.924	5.402	35.1%	0.634	1.253	0.321
1998	4797	12.215	6.082	35.7%	0.714	1.428	0.357
1999	3707	31.133	7.337	37.1%	0.861	1.765	0.420
2000	4005	7.989	5.136	37.9%	0.603	1.254	0.290
2001	2843	87.551	8.518	40.2%	1.000	2.167	0.461



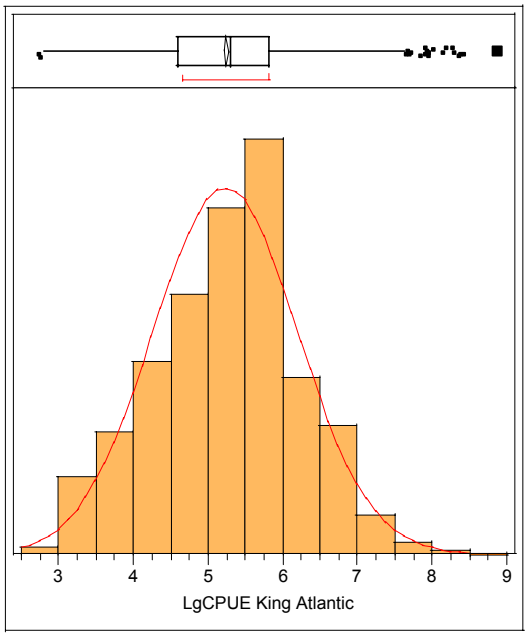
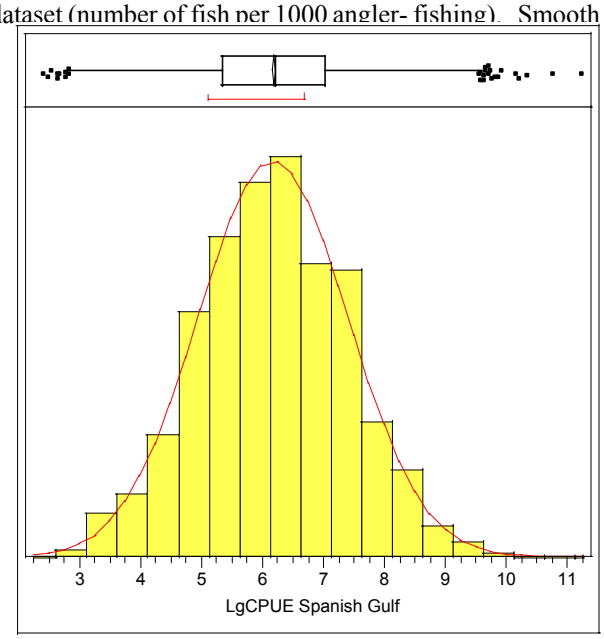


Figure 1. Frequency distribution of king mackerel log-transformed nominal CPUE of positive observations from the MRFSS dataset (number of fish per 1000 angler- fishing). Smooth line repres



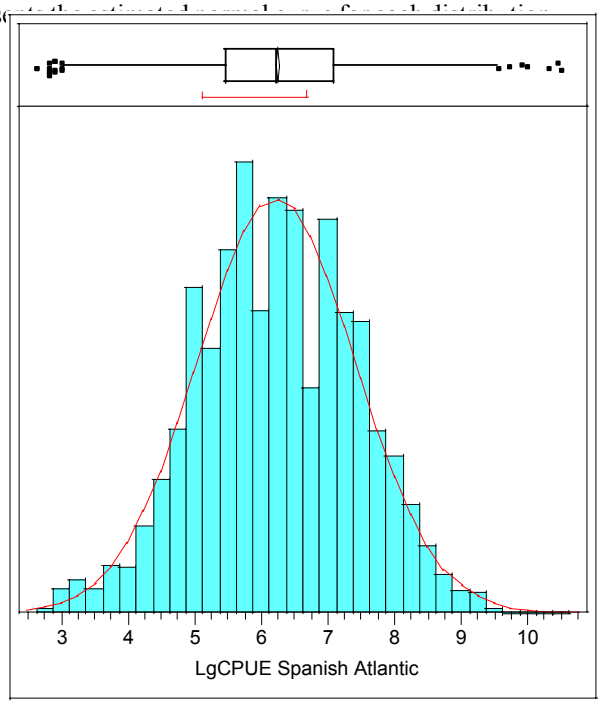


Figure 2. .Frequency distribution of Spanish mackerel log-transformed nominal CPUE of positive observations from the MRFSS dataset (number of fish per 1000 angler fishing). Smooth line represents the estimated normal curve for each distribution

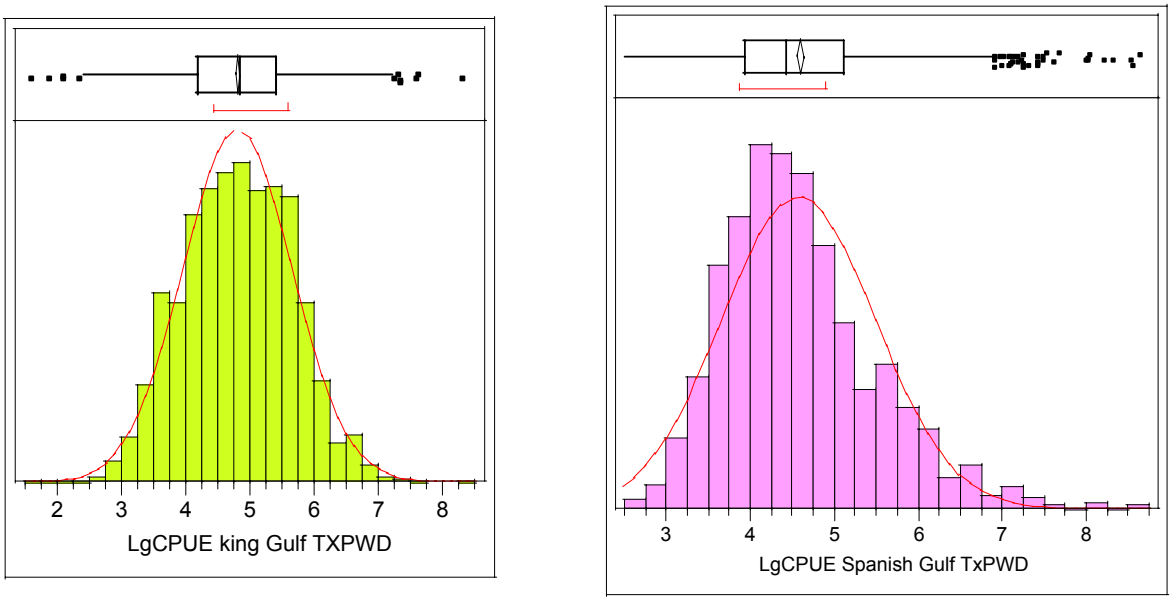


Figure 3. Frequency distribution of log-nominal CPUE of positive trips for king and Spanish mackerel from the Texas PWD angler creel survey data. CPUE is numbers of fish per thousand anglers.

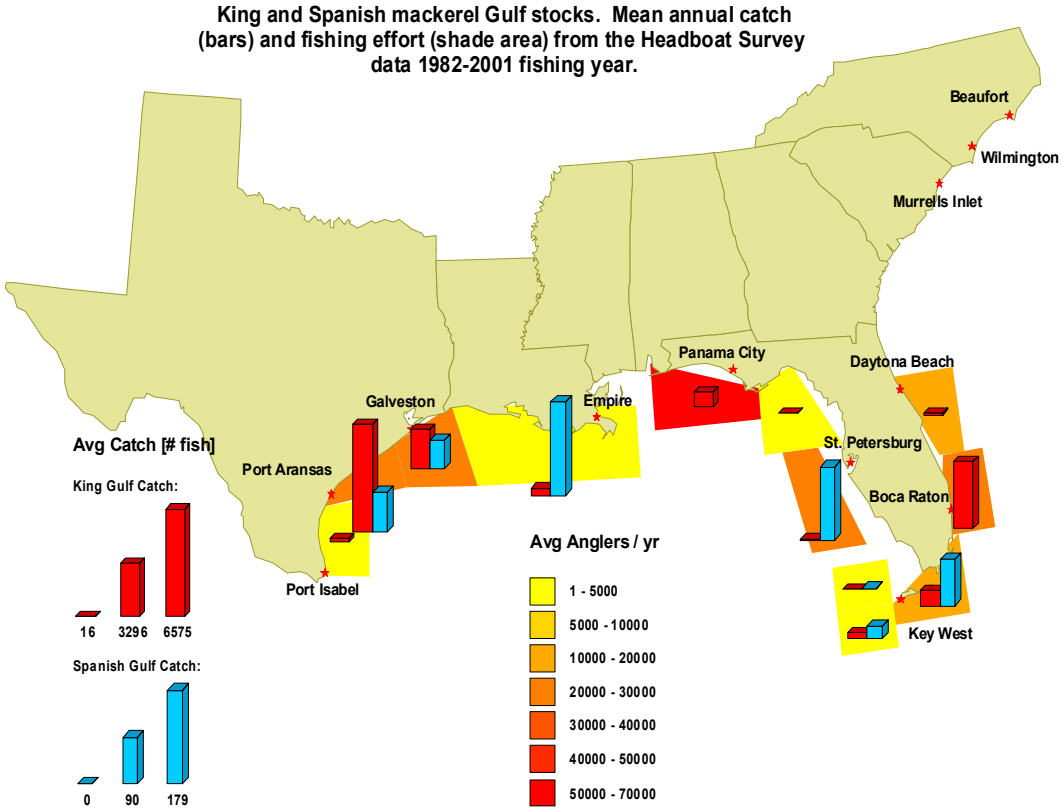


Figure 4. Geographic distribution of catch (bars) and fishin effort (areas) for king and Spanish mackerel Gulf stocks from the Headboat Survey data 1982-2001.

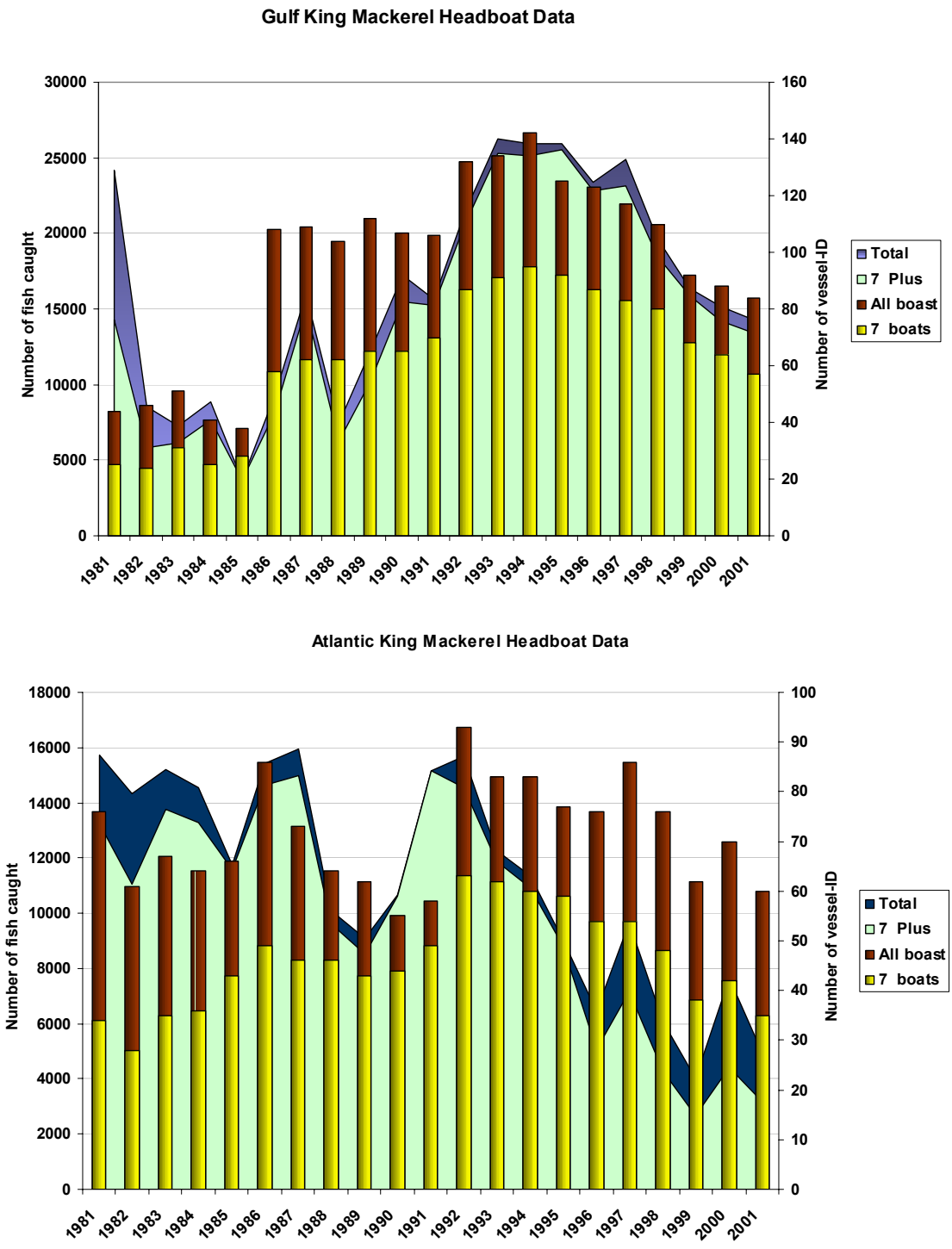


Figure 5. Distribution of catch (area plots) and number of vessels-ID (bars) reported for King mackerel from the Headboat Survey data. Light areas and bars represent the catch and number of vessels that have reported king mackerel catch for at least 7 or more years within the 1981-2001 period, respectively.

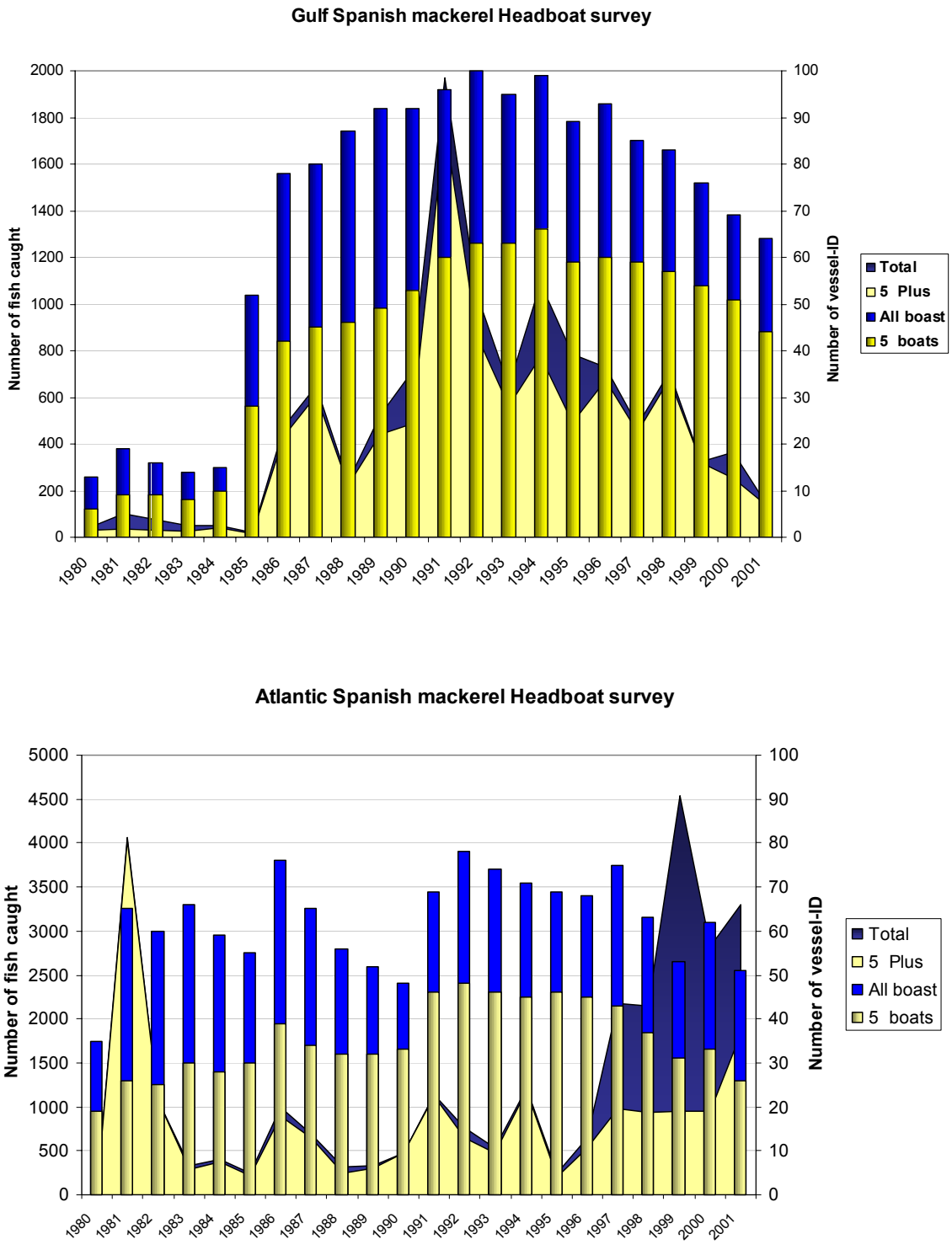


Figure 6. Distribution of catch (area plots) and number of vessels-ID (bars) reported for Spanish mackerel from the Headboat Survey data. Light areas and bars represent the catch and number of vessels that have reported Spanish mackerel catch for at least 5 or more years within the 1981-2001 period, respectively.

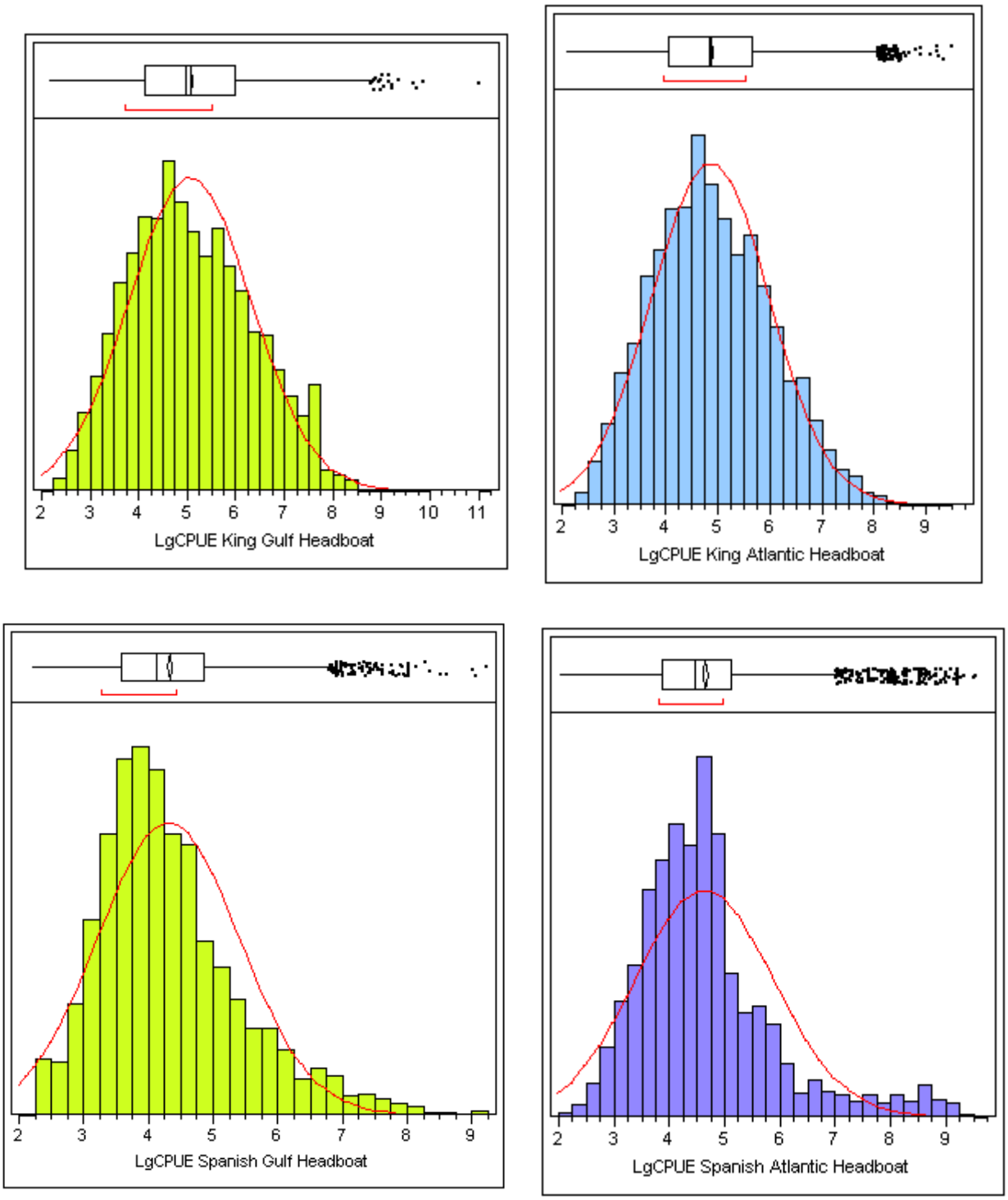


Figure 7. Frequency distribution of nominal log-transformed CPUE for King (top row) and Spanish mackerel (bottom row) for positive trips from the Headboat Survey data. Smooth line represents the estimated normal distribution in each case.

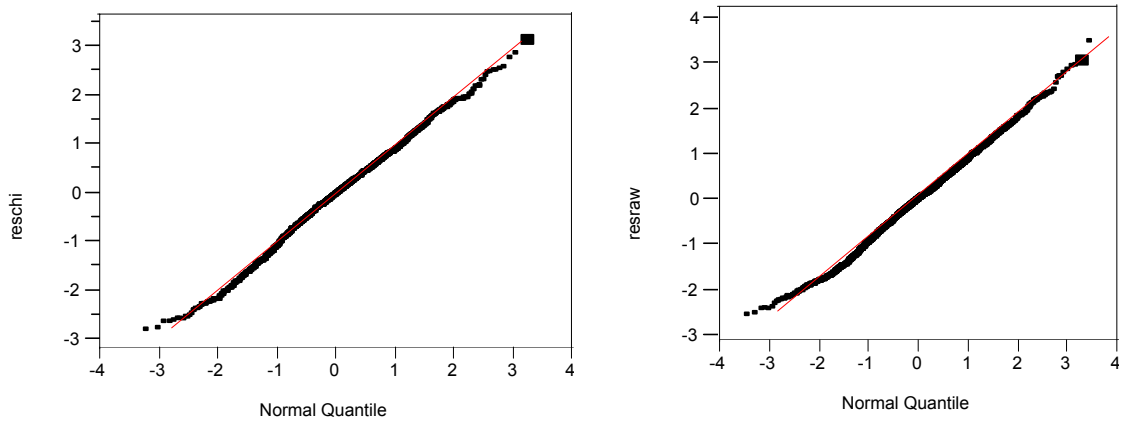


Figure 8. qq-plots of deviance residuals from the delta lognormal model fit of positive observations for king mackerel Atlantic (right) and Gulf (left) stocks, MRFSS dataset.

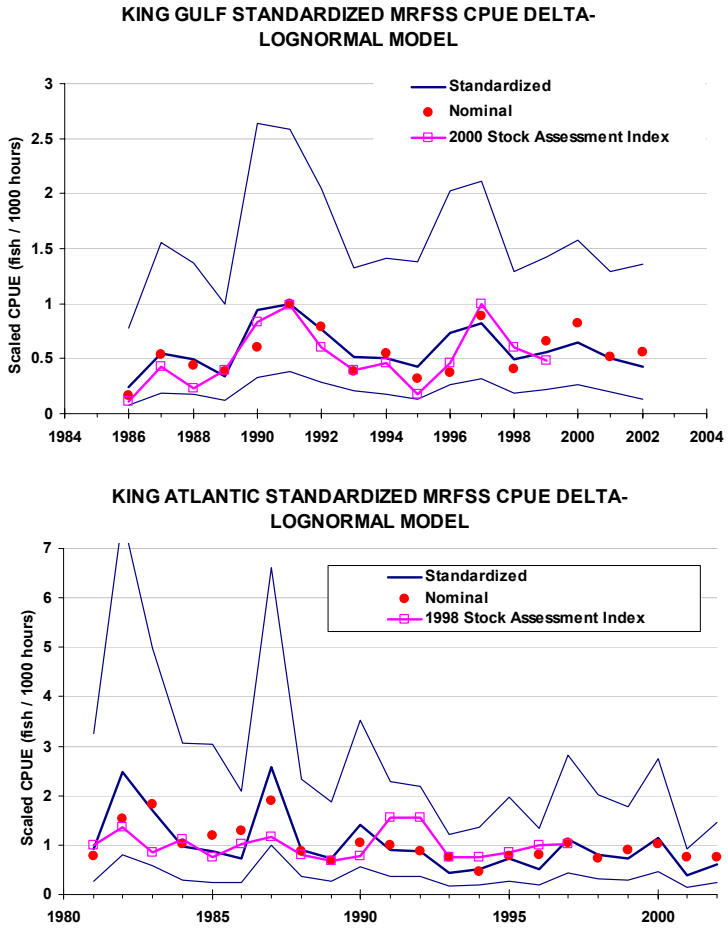


Figure 9. Nominal and standardized CPUE series for king mackerel Atlantic (top) and Gulf (bottom) stocks. Thin lines represent estimated 95% confidence intervals.

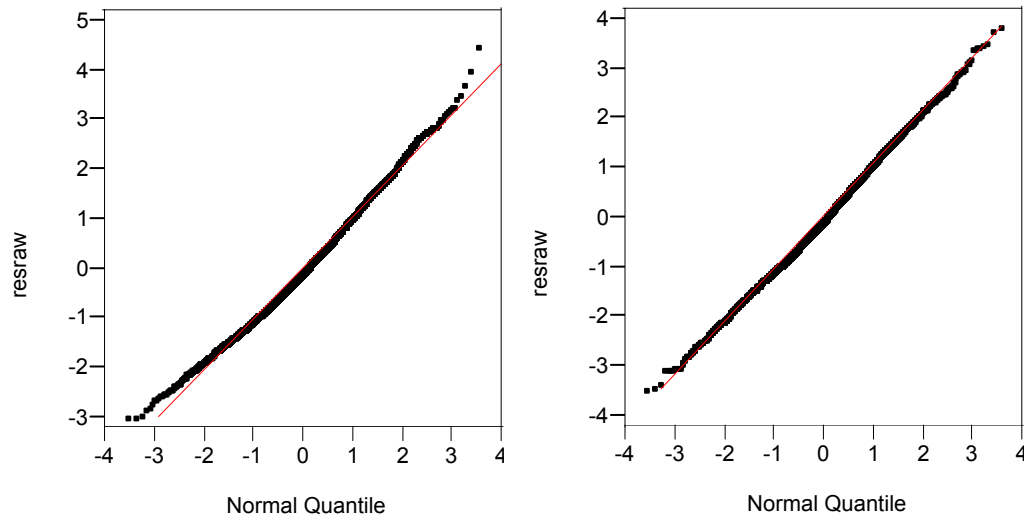
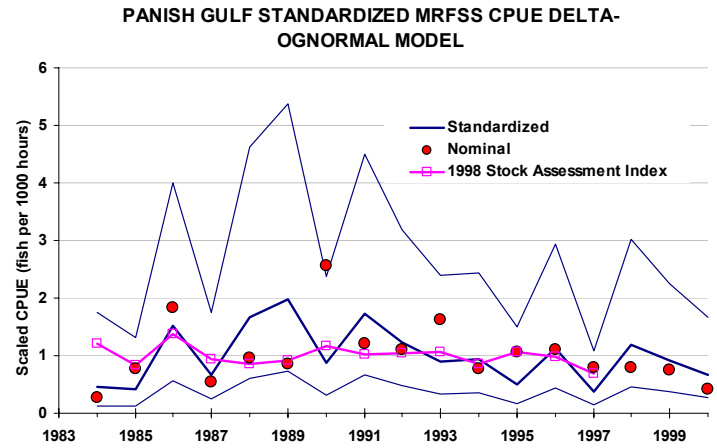


Figure 10. qq-plc : observations for Spanish mackerel Gulf (ri



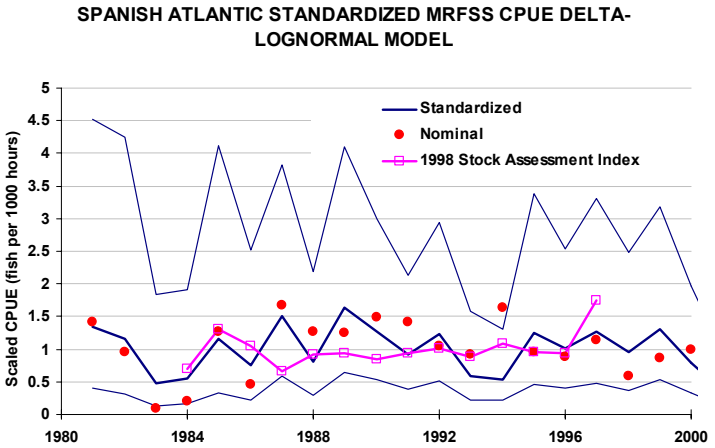


Figure 11. Nominal and standardized CPUE series for Spanish mackerel stocks from the MRFSS data. Thin lines represent estimated 95% confidence intervals.

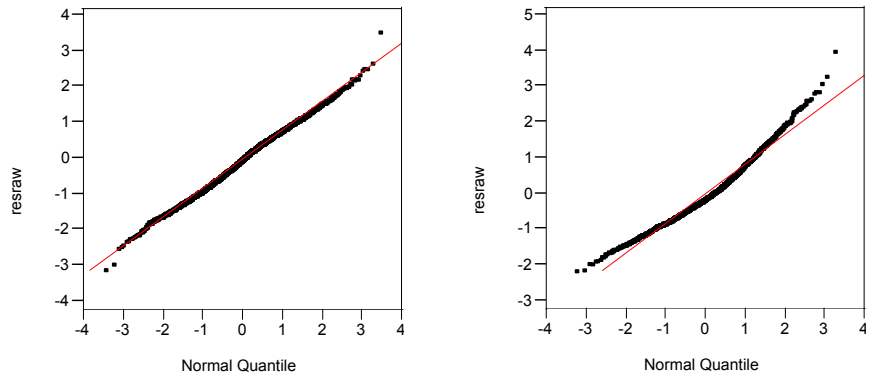
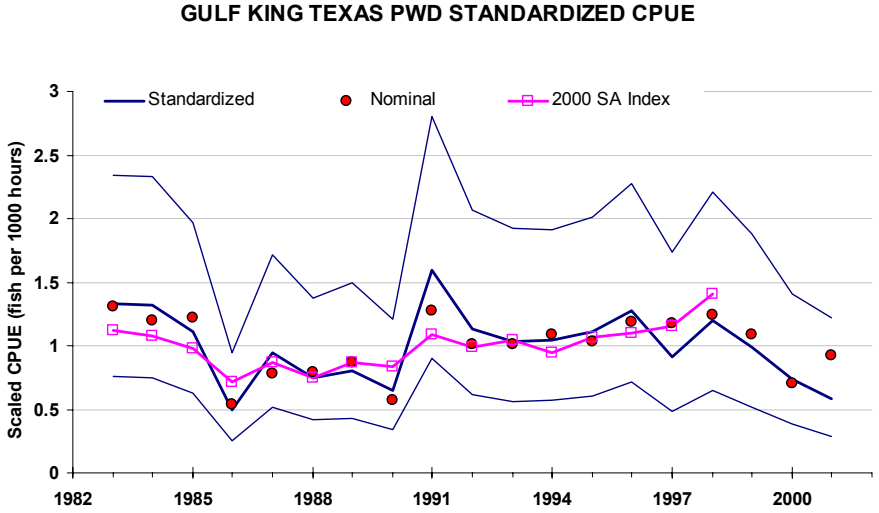


Figure 12. Cumulative normalized deviance residuals (qq-plots) from the positive observations component delta lognormal model for king (left) and Spanish (left) mackerel catch rates TxPWD data.



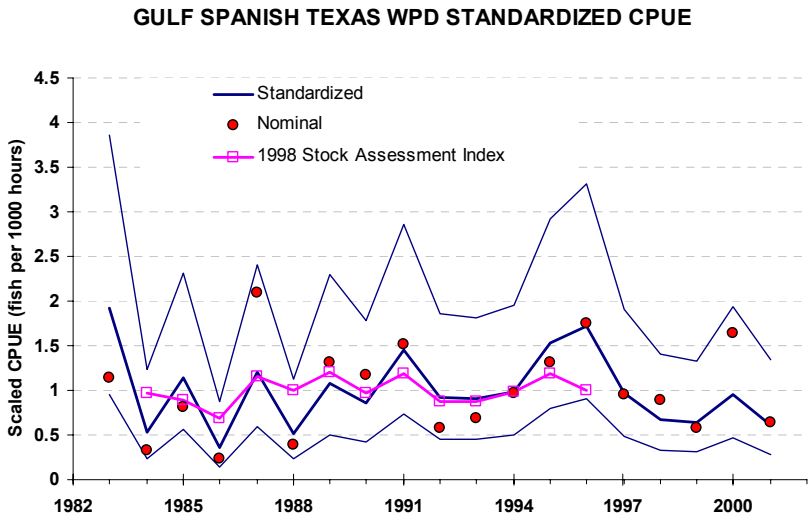


Figure 13. Nominal and standardized CPUE series for king and Spanish mackerel Gulf stocks from the TxPWD data. Thinner lines represent estimated 95 percentage confidence intervals.

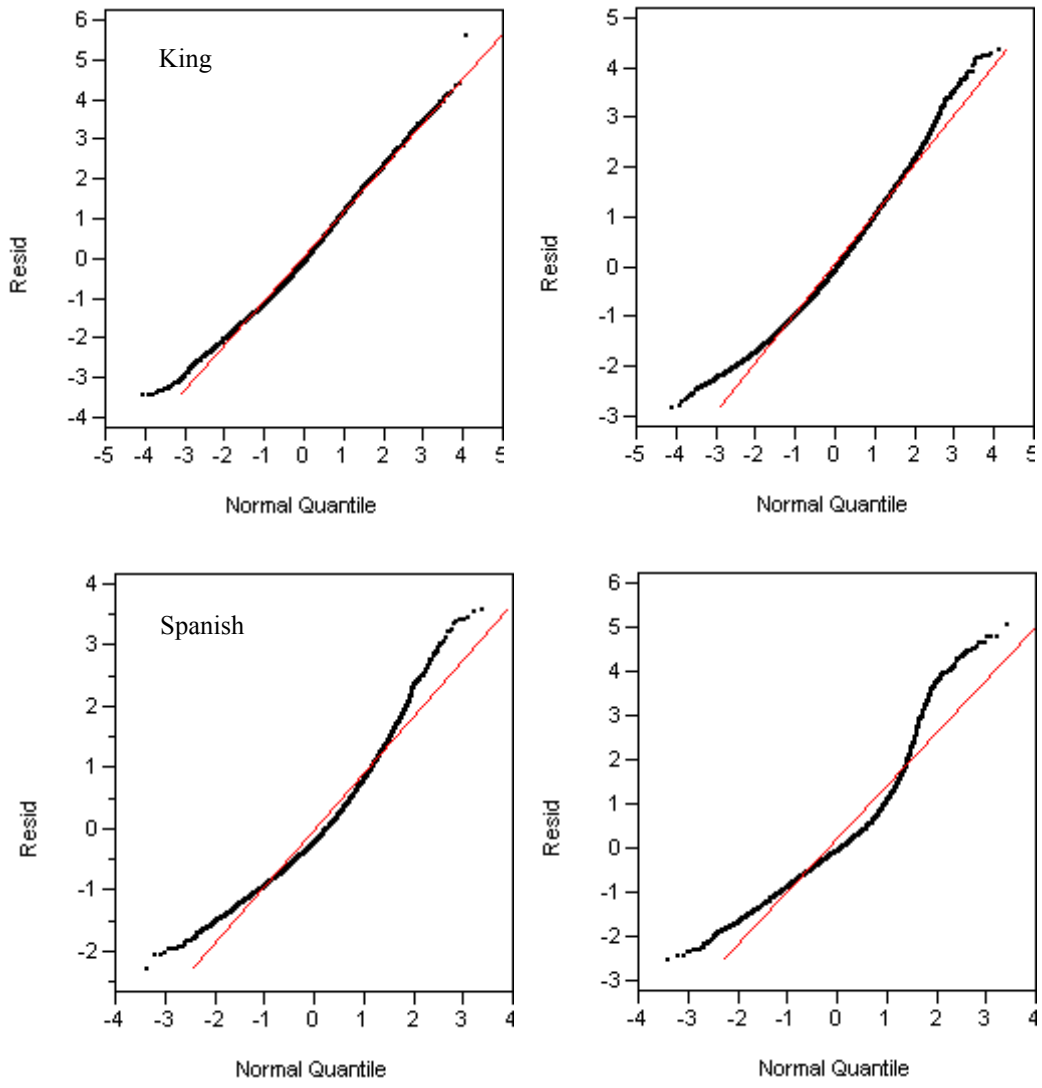


Figure 14. Cumulative normalized deviance residuals from the positive trips component delta lognormal model for Gulf (left) and Atlantic (right) king and Spanish mackerel stocks Headboat data.

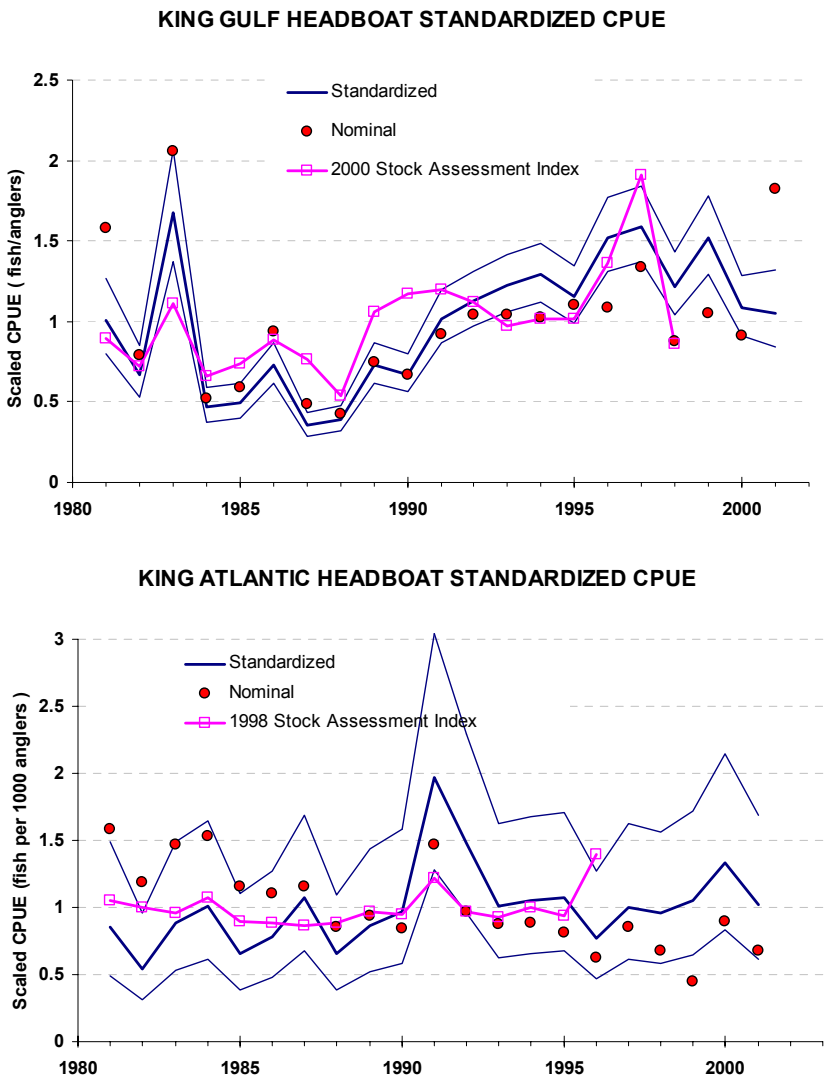


Figure 15. Nominal and standardized catch rates for king mackerel stocks from the Headboat data. Thinner lines represents estimated 95% confidence intervals.

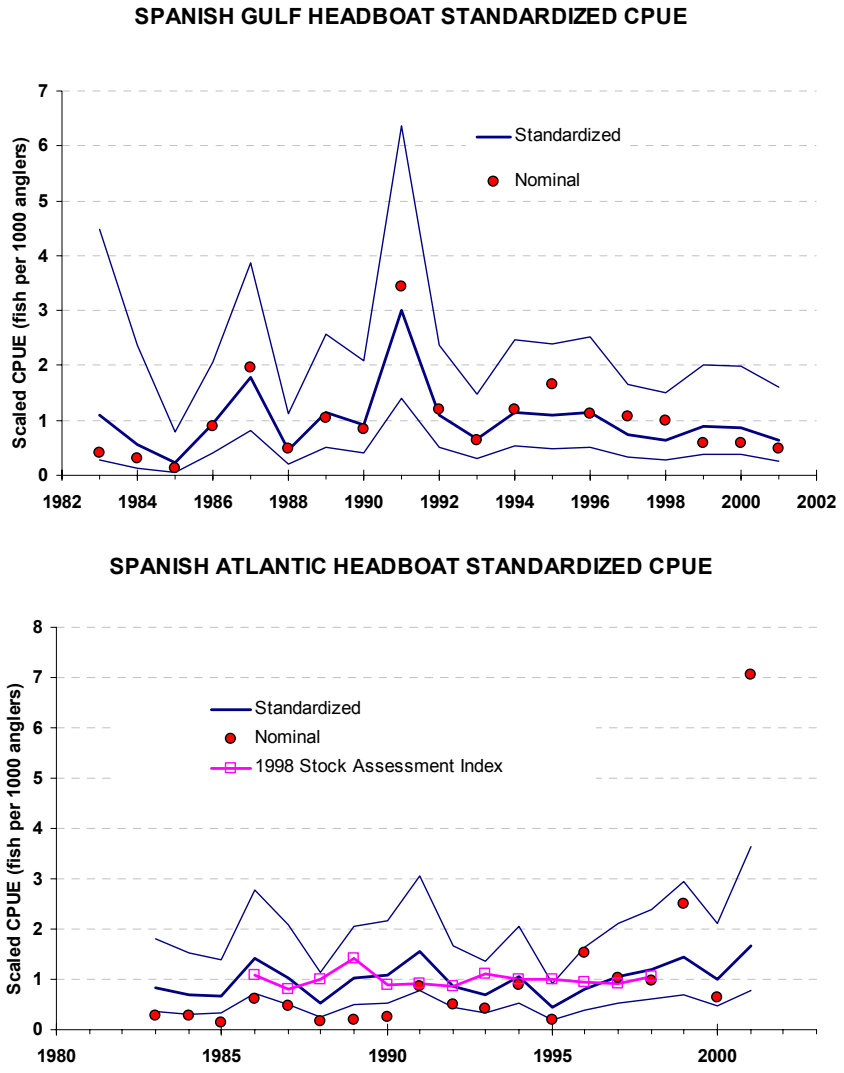


Figure 16. Nominal and standardized catch rates for Spanish mackerel stocks from the Headboat data. Thinner lines represents estimated 95% confidence intervals.

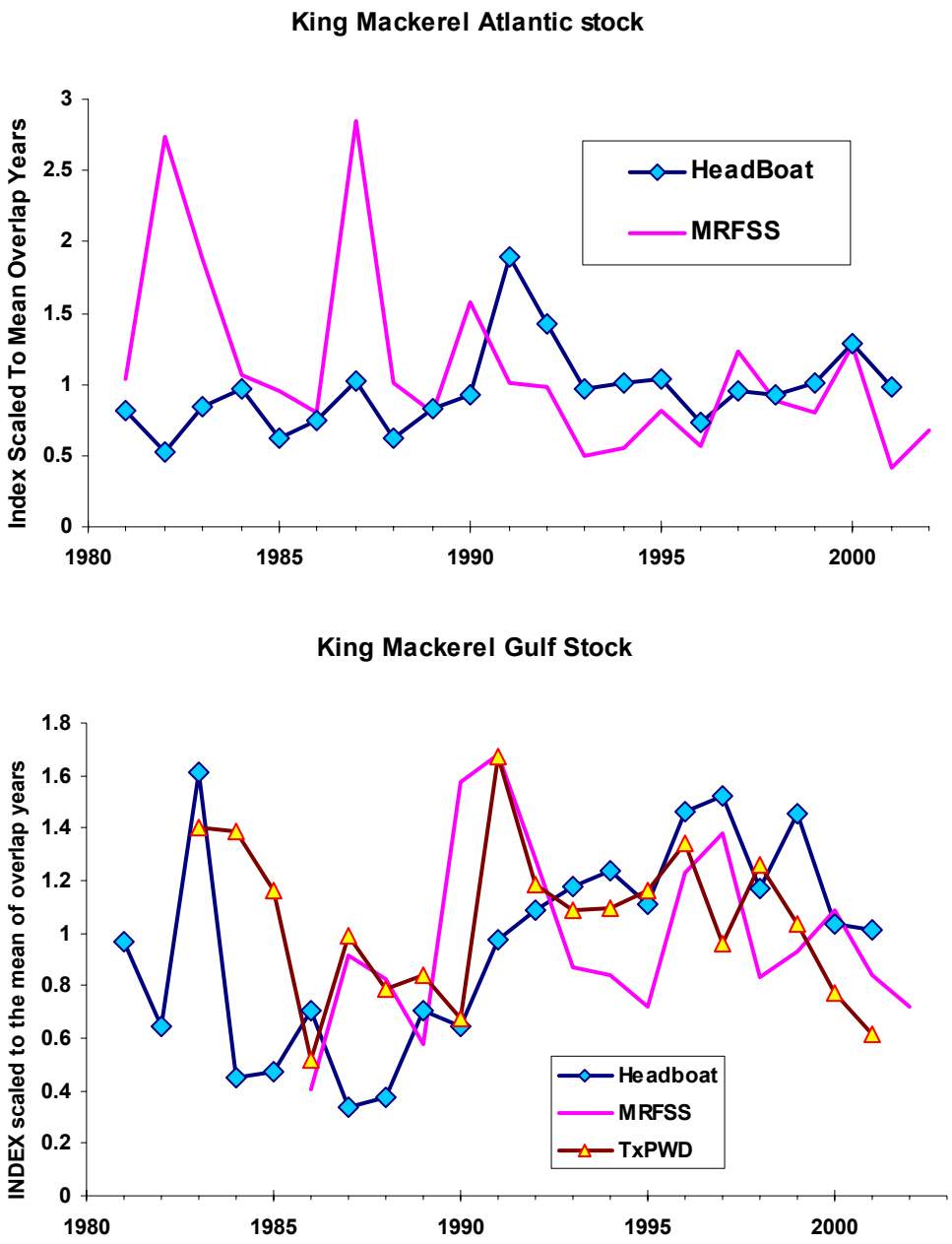
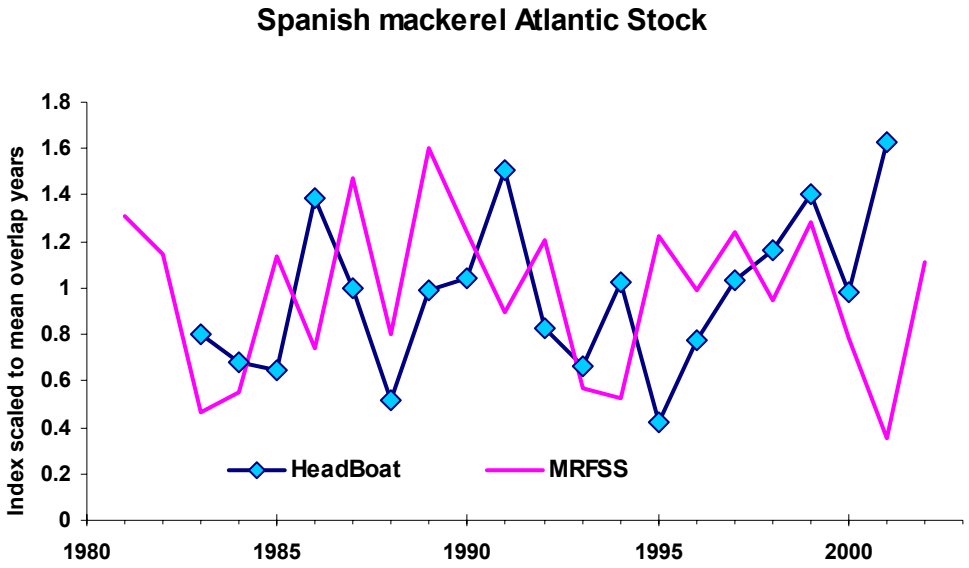


Figure 17. Comparison of standard CPUE series for king mackerel Atlantic and Gulf stocks from recreational fisheries data.



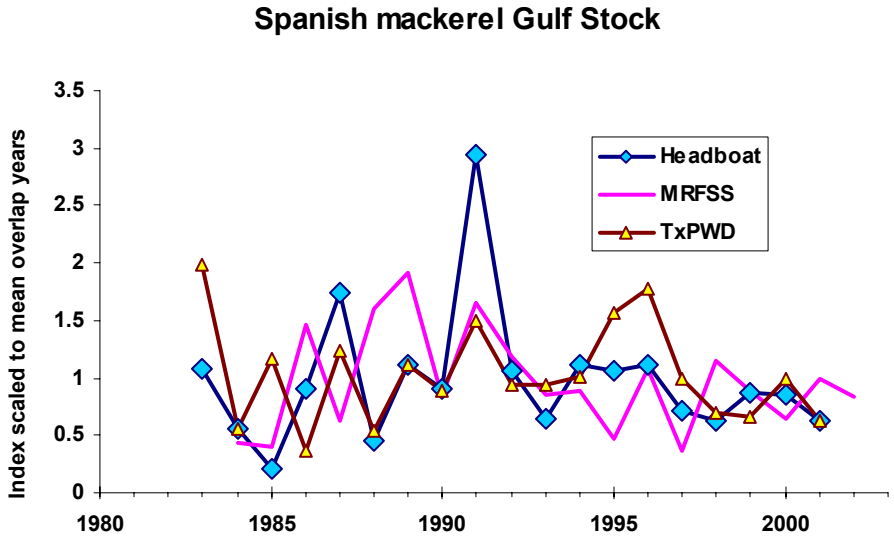


Figure 18. Comparison of standard CPUE series for Spanish mackerel Atlantic and Gulf stocks from recreational fisheries data.