Commercial Vertical Line and Gillnet Vessel Standardized Catch Rates of Spanish Mackerel in the US Gulf of Mexico, 1998-2010

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SEDAR28-DW15

Submitted: 9 February 2012
Revised: 1 March 2012 (Minor grammatical and formatting changes)
Revised: 5 March 2012 (addendum added)

This document should be cited as:

Baertein, N. and K. McCarthy. 2012. Commercial Vertical Line and Gillnet Vessel Standardized Catch Rates of Spanish Mackerel in the US Gulf of Mexico, 1998-2010. SEDAR28-DW15. SEDAR, North Charleston, SC.

Commercial Vertical Line and Gillnet Vessel Standardized Catch Rates of Spanish Mackerel in the US Gulf of Mexico, 1998-2010

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Sustainable Fisheries Division Contribution SFD-2012-005

Introduction

NOAA Fisheries has been monitoring commercial landings and fishing effort of federally managed coastal finfishes in the Gulf of Mexico and U.S. South Atlantic through the Southeast Fisheries Science Center's Coastal Fisheries Logbook Program (CFLP). The CFLP collects landings and effort data by fishing trip which is submitted by fishers who own or operate a federally permitted commercial fishing vessel. Most data collected by the CFLP are for fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. The CFLP data collection began in 1990 to obtain a complete census of the coastal fisheries in the Gulf of Mexico from vessels that possessed a Federal reef fish permit, with the exception of Florida, where only 20 percent of vessels were selected to report until 1993. Also beginning in 1993, South Atlantic Snapper/Grouper and Shark permit holders were required to submit trip reports. Beginning in 1998, all Federal Spanish and King Mackerel permit holders were required to report.

Using the CFLP's available catch per unit effort (CPUE) data, indices of abundance of Spanish mackerel were constructed for the U.S. Gulf of Mexico from 1998 through 2010. The indices were constructed using data submitted by Federally permitted commercial vertical line and gillnet vessels.

Methods

Available Data

Commercial fishing activity reported by fishers to the CFLP is at the trip level. For each fishing trip, the CFLP database includes a unique trip identifier, the landing date, fishing gear deployed, areas fished (Figure 6), number of days at sea, number of crew, gear specific fishing effort, species caught and weight of the landings. Fishing effort data available for vertical gear included number of lines, number of hooks per line, and total hours fished. Vertical gear includes handline (i.e. rod & reel), electric/bandit reel, and trolling. In the case of electric/bandit reel, these data were not collected separately until 2007. Multiple areas fished and multiple gears fished may be recorded for a single fishing trip. In such cases, assigning catch and effort to specific locations or gears was not always possible; therefore, only trips which reported one area category (see area factor below) and one gear fished were included in these analyses. For trips where both handline and electric reel were reported, these trips were kept and total effort summed.

Data were further restricted to include only those trips with landings and effort data received by the CFLP within 45 days of the completion of the trip. Reporting delays beyond 45 days likely results in less accurate effort data. Landings data may still be reliable even with lengthy reporting delays if dealer trip ticket reports were referenced by the reporting fisher. Trips in which errant or missing data were present were removed from

the analyses. These included missing number lines, number of hooks, and hours fished for vertical gear. Vertical gear trips reporting 24 or more hours per day fishing were also excluded. Gillnet trips with missing net length, depth (i.e. width), or hours fished were excluded. Following the exclusion of trips listed above, outliers were removed in which number of lines, and hooks fell outside the upper 99.5 percentile. For gillnet trips, records were dropped when gillnet length or gillnet depth(width) were below the 0.5 percentile or above the 99.5 percentile. Additional gillnet trips were removed from consideration when stake gillnet was reported or when shark landings were reported as this fishing effort were unlikely to land any Spanish mackerel.

For the vertical gear analysis, only positive Spanish mackerel trips were used from 1998 through 2010. All trips were considered for the gillnet index. Gillnet trips were also categorized as having, or not having, a king mackerel gillnet endorsement. Catchability of those vessels likely differs from other gillnet vessels.

Index Development

Vertical Line

Vertical line catch rate was calculated in gutted pounds per hook hour. For each trip, catch per unit effort was calculated as:

CPUE = gutted pounds of Spanish mackerel/ (number of lines * number of hooks per line * hours fished)

Six factors were considered as possible influences on vertical line catch rates of Spanish mackerel. In order to develop a well balanced sample design, the factors were defined as:

Factor	Levels	Value
YEAR	13	1998 – 2010
QUARTER	4	1 (Jan-Mar), 2 (Apr-Jun), 3 (Jul-Sep), 4 (Oct-Dec)
SUBREGION	3	Sub1: 1-3, Sub2: 4-12, Sub3: 13-21
CREW	3	1, 2, 3+ crew members
DAYS_AT_SEA	2	1, 2+ days
GEAR_TYPE	2	TROLLING, VERTICAL (Handline, Rod & Reel, Electric/Bandit)

Gillnet

Gillnet catch rate was calculated in gutted pounds per square yard hour. For each trip, catch per unit effort was calculated as:

CPUE = gutted pounds of Spanish mackerel/ (gillnet length * gillnet width (i.e.depth) * hours fished)

Five factors were considered as possible influences on gillnet proportion of trips that landed Spanish mackerel and the catch rate of Spanish mackerel. In order to develop a well balanced sample design, the below factors were defined. Days at sea were not included as 90% of trips were 1 day trips.

Factor	Levels	Value
YEAR	13	1998 - 2010
CREW	3	1-2, 3, 4+ crew members
SUBREGION	2	Sub1: 1-3, Sub2: 4-17
GN_ENDORSEMENT	2	No, Yes (King mackerel gillnet endorsement)
*TOTAL_EFFORT**	3	<=6K sq yd hrs, 6.1K-36K sq yd hrs, 36.1K + sq yd hrs

* Total effort was included in the proportion positive analysis only

For gillnet, the delta lognormal model approach (Lo et al. 1992) was used to construct a standardized index of abundance. This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed Spanish mackerel) and the catch rates on successful trips to construct a single standardized CPUE index. Since only positive trips were used for the vertical line index construction a lognormal approach used. Parameterization of each model was accomplished using a GLM procedure (GENMOD; Version 8.02 of the SAS System for Windows © 2000. SAS Institute Inc., Cary, NC, USA).

Significant effects on the proportion of positive trips and on the CPUE of positive trips of the above factors were tested using general linear model (GLM) analyses. For the GLM analyses of proportion positive trips, a type-3 model was fit, a binomial error distribution was assumed, and the logit link was selected. The response variable was proportion successful trips. For the analyses of catch rates on successful trips, a type-3 model assuming lognormal error distribution was examined. The linking function selected was "normal", and the response variable was log(CPUE). The response variable of data was calculated as: log(CPUE) = ln(pounds of Spanish mackerel/hook hour) for vertical line and : log(CPUE) = ln(pounds of Spanish mackerel/square yard hours) for gillnet. All 2-way interactions among significant main effects were examined. Higher order interaction terms were not examined.

A forward stepwise regression procedure was used to determine the set of fixed factors and interaction terms that explained a significant portion of the observed variability. Each potential factor was added to the null model sequentially and the resulting reduction in deviance per degree of freedom was examined. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant based upon a Chi-Square test ($p<0.05$), and the reduction in deviance per degree of freedom was $\geq 1\%$. These significant factors were input as the base model, and the process was repeated, adding factors and two-way interactions individually until no factor or interaction met the criteria for incorporation into the final model.

For gillnet, the final delta-lognormal model was fit using a SAS macro, GLMMIX (Russ Wolfinger, SAS Institute). For vertical trips however, only positive trips were included and a lognormal model was used for index construction. The lognormal model was fit using a PROC MIXED SAS procedure (Version 9.2 SAS Institute). All factors were modeled as fixed effects except two-way interaction terms containing YEAR which were examined as random effects to be included in the final model. Selection of the final mixed model was based on the Akaike's Information Criterion (AIC), Schwarz's Bayesian Criterion (BIC), and a chi-square test of the difference between the –2 log likelihood statistics between successive model formulations (Littell et al. 1996). For comparison, a relative index and relative nominal CPUE series were calculated by dividing each value in the series by the mean value of the series.

Results and Discussion

The final models for the binomial on proportion positive trips (PPT) and the lognormal on CPUE of successful trips were:

Vertical Line

PPT = No binomial model

LOG(CPUE) = Year + Days_at_sea + Subregion + Quarter + Days_at_sea*Subregion + Subregion*Quarter

Gillnet

PPT = Year + Total_effort + GN_Endorsement + Subregion + Total_effort*GN_Endorsement

LOG(CPUE) = Year + Subregion + Year*Subregion

The linear regression statistics and analyses of the mixed model formulations of the final models are summarized in Table 1.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index are provided in Table 2. The delta-lognormal (gillnet) and lognormal (vertical line) abundance indices constructed, with 95% confidence intervals, are shown in Figure 1.

Plots of the proportion of positive trips per year, nominal cpue, frequency distributions of the proportion of positive trips, frequency distributions of log(CPUE) for positive catch, cumulative normalized residuals, and plots of chi-square residuals by each main effect for the binomial and lognormal models are shown in Figures 2-5. Those diagnostic plots indicate that the fit of the data to the lognormal and binomial models were acceptable. There were some outliers among these data, however, and the frequency distribution of log(CPUE) from these data were somewhat skewed from the expected normal distribution. Those variations from the expected fit of the data were not sufficient to violate assumptions of the analyses. The observed positive Spanish mackerel for gillnet trips ranged from approximately 37 to 79%. Data from only positive trips were included in the vertical line analysis.

Spanish mackerel standardized catch rates for vertical line show slight increases from 2000-2006 and again in 2008-2010. However the overall trend appears to be relatively flat. Coefficients of variation remained very low and constant over the time series ranging from 0.08-0.14. Gillnet catch rates appeared to be highly variable with peaks in 2003 through 2005 and again in 2010. The catch rates during these four years were about four times the rate of the rest of the time series. High upper confidence limits were seen in these years as well, with the highest being 10.9 in 2010. As expected, high coefficients of variation were seen ranging between 0.8 and 1.4. Overall however the gillnet index remained relatively flat. This stability in the overall catch rate trend may be due to the efficiency and selectivity of runaround gillnets used on schooling fish (Hilborn and Walters 1992).

Literature Cited

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

Lo, N.C., L.D. Jackson, 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.

Hilborn, R., and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty. Chapman and Hall, New York. 570p.

Table 1. (A) Vertical line, **(B)** gillnet. Linear regression statistics for the GLM models on (**i**) catch rates on positive trips and (**ii**) proportion positive trips (gillnet only) of Spanish mackerel in the Gulf of Mexico for vessels reporting 1998-2010. (**iii**) Analysis of the mixed model formulations of the positive trip model (gillnet only). The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final model is indicated with gray shading. See text for factor (effect) definitions.

A. Vertical line

i.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	12	4601	2.39	0.0045
DAYS_AT_SEA	1	4601	514.14	<.0001
SUBREGION	2	4601	41.06	<.0001
QUARTER	3	4601	18.98	<.0001
*DAYS_AT_SEA*SUBREGION*	2	4601	55.81	<.0001
*SUBREGION*QUARTER*	6	4601	17.27	<.0001

ii. No binomial component for vertical gear

B. Gillnet

i.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
YEAR	12	11	8.05	0.67	0.7810	0.7484
SUBREGION	1	11	4.61	4.61	0.0318	0.0549

ii.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
TOTAL_EFFORT	2	68	57.47	28.74	<.0001	<.0001
GN_ENDORSEMENT	1	68	9.94	9.94	0.0016	0.0024
YEAR	12	68	31.02	2.58	0.0020	0.0069
SUBREGION	1	68	11.29	11.29	0.0008	0.0013
*TOTAL_EFFORT*GN_ENDORSE*	2	68	11.14	5.57	0.0038	0.0057

iii.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
YEAR + SUBREGION	2596.6	2598.6	2603.0	-	-
*YEAR + SUBREGION + YEAR*SUBREGION*	2539.4	2543.4	2545.8	57.2	<0.0001

Table 2. Gulf of Mexico relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for Spanish mackerel (1998-2010) for **(A)** vertical line and **(B)** gillnet gears.

A. Vertical Line

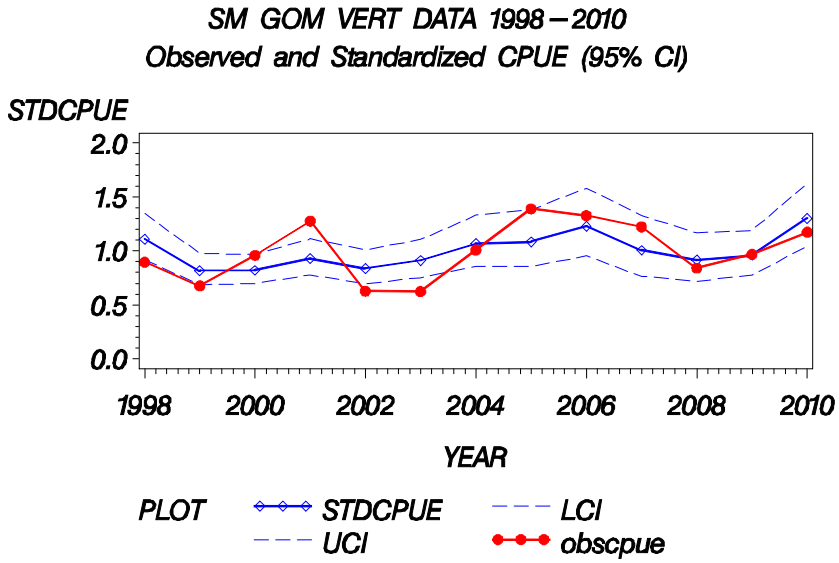
YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.896733	407	1.0	1.110020	0.916881	1.343842	0.095796
1999	0.676905	484	1.0	0.818040	0.685334	0.976443	0.088676
2000	0.959316	602	1.0	0.821822	0.698381	0.967081	0.081515
2001	1.277024	475	1.0	0.928847	0.776205	1.111506	0.089945
2002	0.627930	442	1.0	0.839362	0.697565	1.009984	0.092722
2003	0.624959	409	1.0	0.912561	0.753036	1.105879	0.096293
2004	1.008903	296	1.0	1.067666	0.856744	1.330516	0.110380
2005	1.390524	246	1.0	1.085462	0.853211	1.380934	0.120814
2006	1.328267	219	1.0	1.229151	0.955510	1.581158	0.126418
2007	1.224061	182	1.0	1.006811	0.764985	1.325084	0.137994
2008	0.841146	242	1.0	0.915937	0.718186	1.16814	0.122061
2009	0.969648	323	1.0	0.961957	0.777388	1.190346	0.106818
2010	1.174585	301	1.0	1.302363	1.043055	1.626136	0.111356

B. Gillnet

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	1.31587	66	0.77273	0.56137	0.09827	3.2068	1.06611
1999	0.85971	153	0.75163	0.36191	0.07981	1.6411	0.87785
2000	0.66704	105	0.66667	0.25462	0.05378	1.2054	0.91108
2001	0.59857	89	0.77528	0.80905	0.19655	3.3302	0.80595
2002	0.45216	62	0.66129	0.07050	0.00871	0.5705	1.40818
2003	1.26842	43	0.62791	2.19239	0.51953	9.2518	0.82409
2004	1.56015	41	0.58537	2.06259	0.48658	8.7433	0.82740
2005	1.17250	47	0.65957	2.37125	0.56209	10.0034	0.82386
2006	0.82636	25	0.60000	0.19907	0.04456	0.8892	0.86644
2007	0.79055	49	0.69388	0.70306	0.16638	2.9709	0.82508
2008	0.95515	46	0.52174	0.56617	0.12659	2.5321	0.86735
2009	1.59290	102	0.79412	0.57952	0.13959	2.4059	0.81215
2010	0.94061	27	0.37037	2.26850	0.47157	10.9126	0.92363

Figure 1. Spanish mackerel nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing **(A)** vertical line gear in the Gulf of Mexico, and **(B)** gillnet gear in the Gulf of Mexico.

A. Vertical Line



B. Gillnet

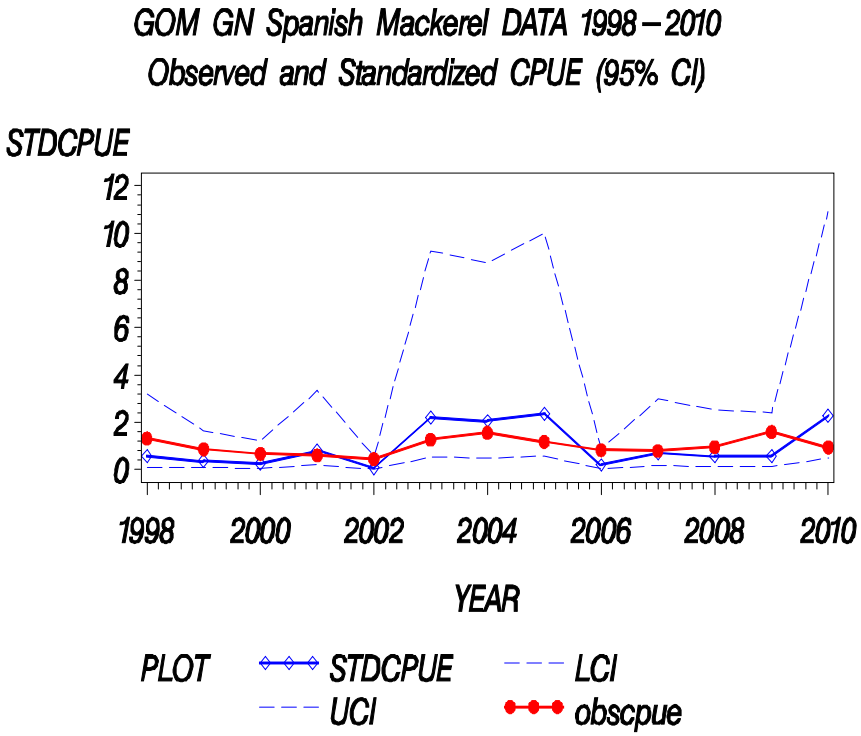
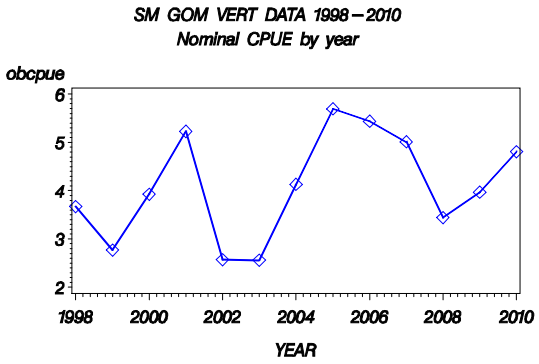


Figure 2. Annual trend in **(i)** the nominal CPUE and **(ii)** proportion of positive trips (gillnet only) for 1998-2010 Spanish mackerel commercial fishing **(A)** vertical line gear in the Gulf of Mexico, and **(B)** gillnet gear in the Gulf of Mexico.

A. Vertical Line

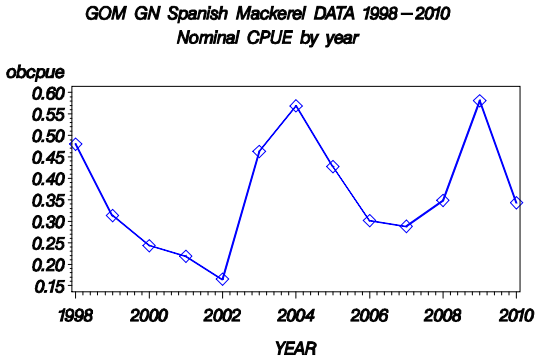
i.



ii. Proportion positives only.

B. Gillnet

i.



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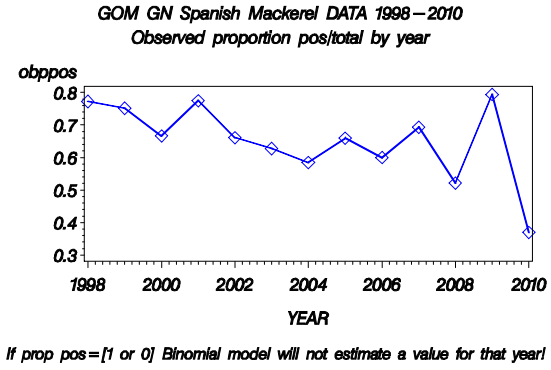
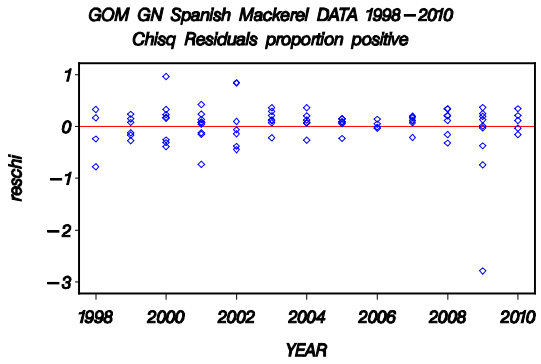


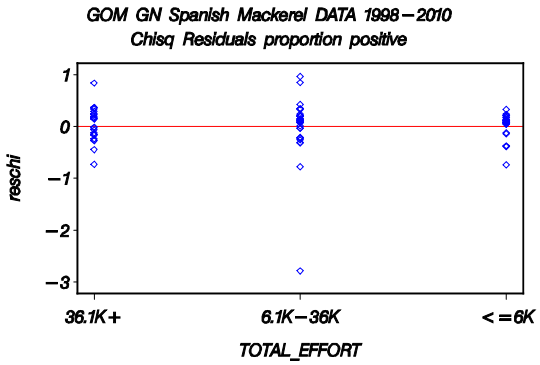
Figure 3. Diagnostic plots for the binomial component of Gulf of Mexico 1998-2010 Spanish mackerel commercial gillnet gear model: **(i)** the Chi-Square residuals by year; (**ii)** the Chi-Square residuals by square yard hours fished; and **(iii)** the Chi-Square residuals by Gillnet endorsement type.

Gillnet

i.



ii.



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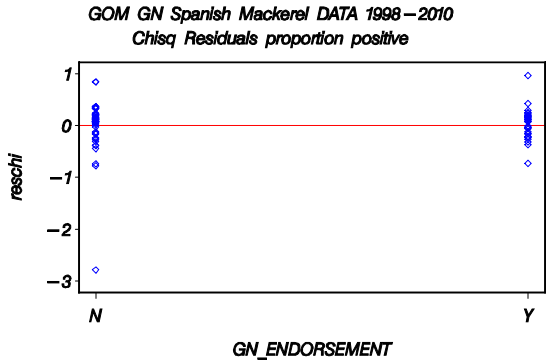
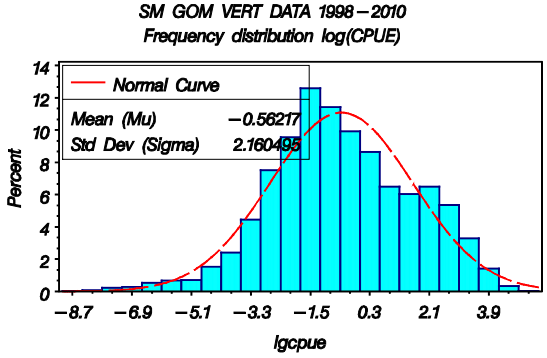


Figure 4. Diagnostic plots for the lognormal component of **(A)** vertical line, and **(B)** gillnet of Spanish mackerel in the Gulf of Mexico, 1998-2010 gear model: **(i)** the frequency distribution of log(CPUE) on positive trips, **(ii)** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A. Vertical line

i.



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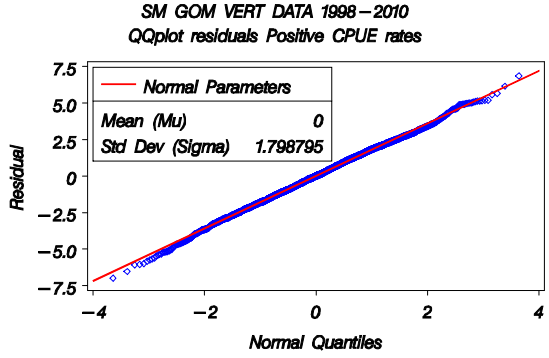
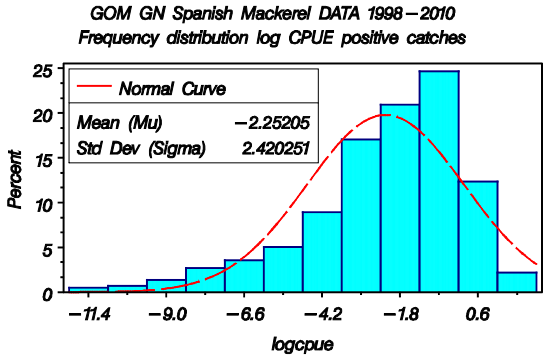


B. Gillnet

i.



ii.

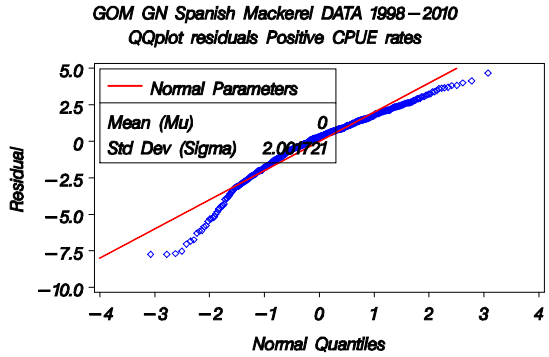
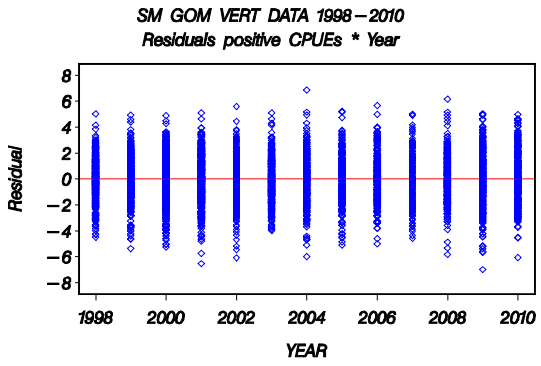


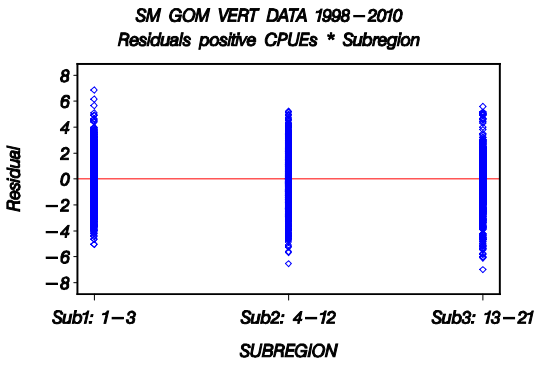
Figure 5. Diagnostic plots for the lognormal component of **(A)** vertical line, and **(B)** gillnet of Spanish mackerel in the Gulf of Mexico, 1998-2010 gear model: **(i)** the Chi-Square residuals by year; **(ii)** the Chi-Square residuals by subregion; **(iii)** the Chi-Square residuals by quarter (vertical gear only); and **(iv)** the Chi-Square residuals by days at sea (vertical gear only).

A. Vertical Line

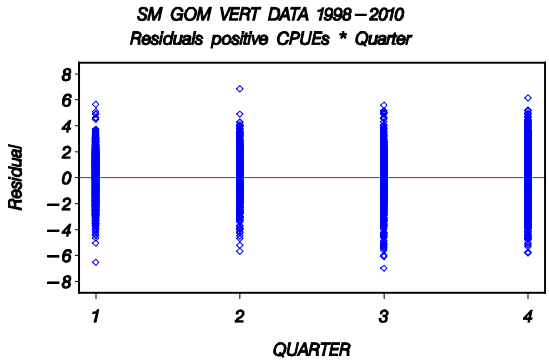
i.



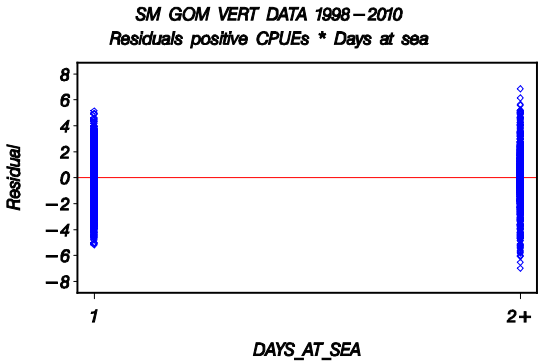
ii.



iii.

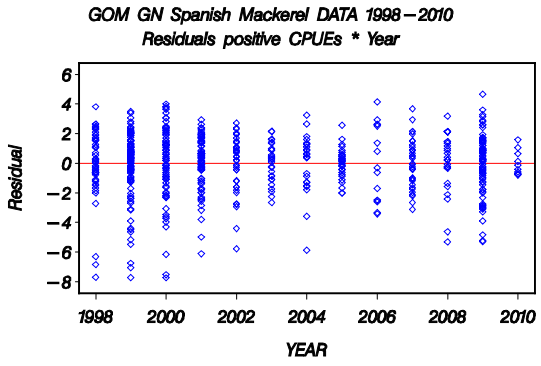


iv.



B. Gillnet

i.



ii.

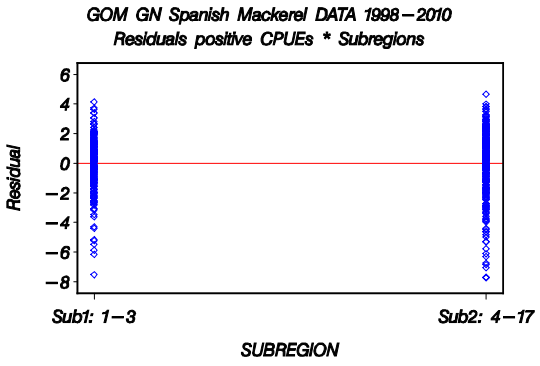
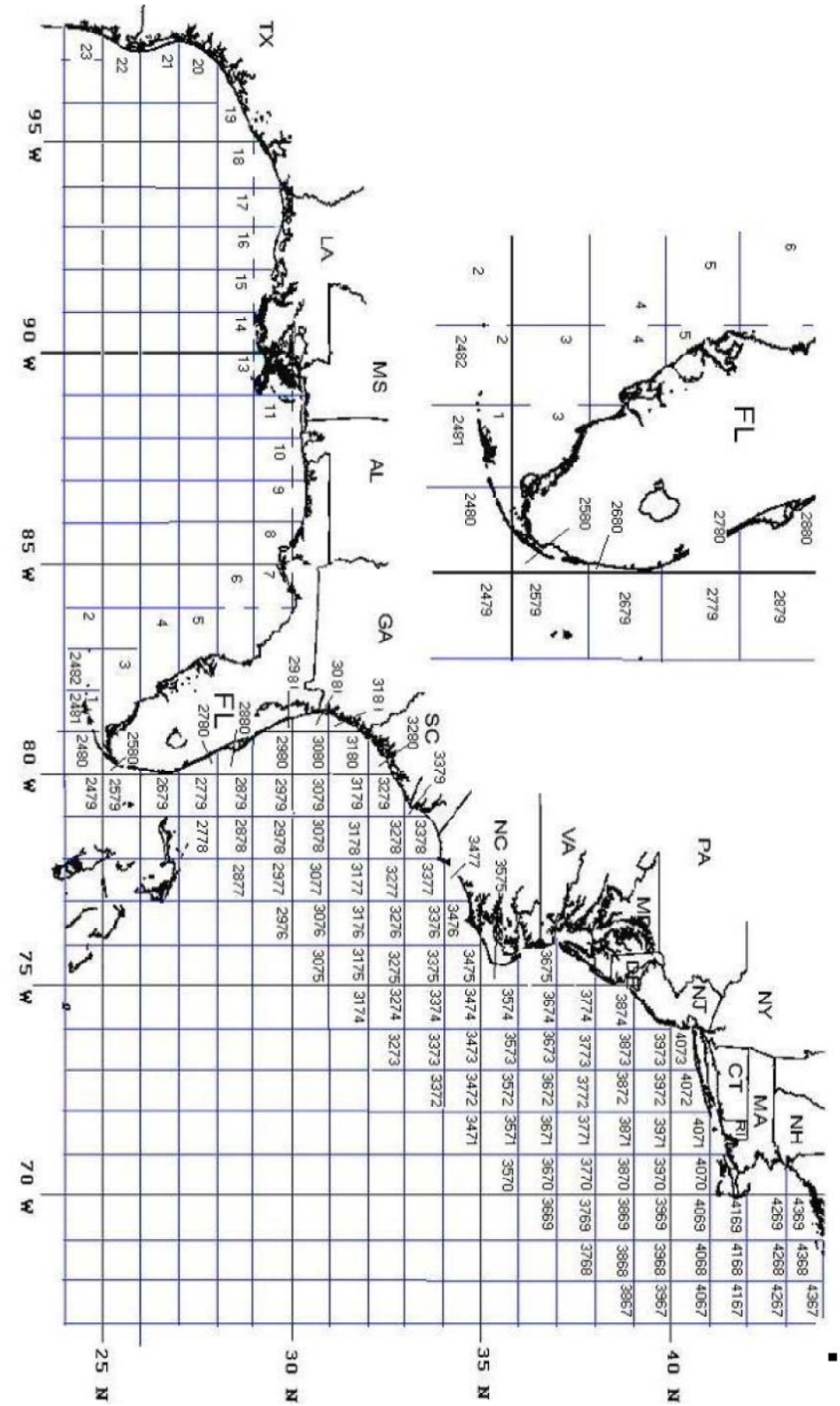


Figure 6. CFLP statistical grid area map



Commercial Vertical Line and Gillnet Vessel Standardized Catch Rates of Spanish Mackerel in the US Gulf of Mexico, 1998-2010: ADDENDUM

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Sustainable Fisheries Division Contribution SFD-2012-005

Introduction

An initial index of abundance was constructed for Spanish mackerel in the Gulf of Mexico using vertical line data collected by the Coastal Fisheries Logbook Program (CFLP) (SEDAR28-DW-15), however the indices workgroup had decided to use the Florida Trip Ticket (FLTT) program index for the Gulf of Mexico as it demonstrated the same general trend over the common years, 1998-2010, however the FLTT index possessed a longer time series dating back to 1986. It was also felt that that since the waters off Florida likely held the bulk of the Gulf of Mexico Spanish mackerel stock, that the Florida Trip Ticket index would be representative of the Gulf stock. As a point of reference however, it had been recommended that a Western Gulf of Mexico index be constructed from the CFLP data.

Methods

Available Data

Data description and refinement methods are described in SEDAR28-DW-15. For this index, data were subset from the previous dataset by using only data where the reported areas of fishing were west of the mouth of the Mississippi River. These areas include statistical grid areas 13 through 19 (Figure 6). Some factor categories may have been redefined to accommodate the smaller dataset.

Index Development

Methods used for index construction were the same as those reported in SEDAR28-DW-15. Most factors that were considered as possible influences on the vertical line catch rate of Spanish mackerel were unchanged from the initial index. Possible area effects were not tested as the whole Western Gulf of Mexico was treated as one area. A season factor was also slightly modified. The initial index tested season by quarter, but for this analysis season was classified as summer (June-September) and non-summer. The calculation of CPUE remained unchanged. Determination of the set of fixed factors using a general linear model (GLM) analyses of the catch rates on successful trips was unchanged. As before, the final lognormal model was fit using a PROC MIXED SAS procedure (Version 9.2 SAS Institute.) Two-way interaction effects containing YEAR were examined as random effects to be included in the final model.

Five factors were considered as possible influences on vertical line catch rates of Spanish mackerel. In order to develop a well balanced sample design, the factors were redefined as:

Factor	Levels	Value
YEAR	13	1998 - 2010
SEASON	2	Summer (Jun-Sep), non-Summer (Jan-May,Oct-Dec)
CREW	2	1, 2+ crew members
DAYS_AT_SEA	3	1, 2, 3+ days
GEAR_TYPE	2	TROLLING, VERTICAL (Handline, Rod & reel, Electric, Bandit)

Results and Discussion

The final model for the lognormal on CPUE of successful trips was:

Spanish mackerel vertical line 1998-2010:

LOG(CPUE) = Year + Gear type + Days at Sea + Crew +
Gear type*Crew + Gear type*Year + Days at Sea*Year

The linear regression statistics and analysis of the mixed model formulations of the final models are summarized in Table 1. Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index are provided in Table 2. The lognormal abundance index constructed, with 95% confidence intervals, is shown in Figure 1. Plots of the nominal CPUE, frequency distributions of log(CPUE) for positive catch, cumulative normalized residuals, and plots of chi-square residuals by each main effect for the lognormal models are shown in Figures 2 through 4. The diagnostic plots indicate that the fit of the data to the lognormal model was acceptable.

As can be seen in Figure1, the index had relatively large confidence intervals and remained relatively flat over the time series. The coefficients of variation were noticeably larger when compare to the Gulf-wide index, ranging from 0.48 to 0.52. When plotted with the Gulf-wide CLFP index (Figure 5), the Gulf-wide index falls within the 95% confidence intervals of the Western Gulf index.

Table 1. Vertical line linear regression statistics for the GLM models on **(i)** catch rates on positive trips of Spanish mackerel in the Western Gulf of Mexico for vessels reporting 1998-2010. **(ii)** Analysis of the mixed model formulations of catch rates on positive trips. The likelihood ratio was used to test the difference of –2 REM log likelihood between two nested models. The final model is indicated with gray shading. See text for factor (effect) definitions.

i.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*F Value*	*Pr > F*
YEAR	12	12	0.53	0.8560
GEAR_TYPE	1	12	38.96	<.0001
DAYS_AT_SEA	2	24	13.79	0.0001
CREW	1	995	26.59	<.0001
*GEAR_TYPE*CREW*	1	995	20.91	<.0001

ii.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
YEAR + GEAR_TYPE + DAYS_AT_SEA + CREW	3994.2	3996.2	4001.1	-	-
*YEAR + GEAR_TYPE + DAYS_AT_SEA + CREW + GEAR_TYPE*YEAR*	3962.4	3966.4	3968.9	31.8	<0.0001
*YEAR + GEAR_TYPE + DAYS_AT_SEA + CREW + GEAR_TYPE*YEAR + DAYS_AT_SEA*YEAR*	3957.3	3963.3	3967.1	5.1	0.0239

Table 2. Western Gulf of Mexico vertical line relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for Spanish mackerel (1998-2010) .

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1998	0.729	78	1.0	1.012	0.400	2.560	0.490
1999	0.413	87	1.0	1.179	0.472	2.947	0.483
2000	0.571	125	1.0	1.622	0.658	3.999	0.475
2001	0.382	88	1.0	0.781	0.313	1.943	0.481
2002	0.966	143	1.0	1.040	0.422	2.563	0.475
2003	0.932	79	1.0	0.912	0.365	2.277	0.483
2004	1.661	99	1.0	1.574	0.636	3.900	0.478
2005	0.228	53	1.0	0.590	0.233	1.493	0.490
2006	1.127	49	1.0	0.799	0.314	2.030	0.493
2007	1.176	27	1.0	0.731	0.277	1.934	0.516
2008	1.804	97	1.0	0.943	0.380	2.341	0.479
2009	1.820	60	1.0	0.597	0.237	1.503	0.488
2010	1.190	64	1.0	1.220	0.482	3.092	0.491

Figure 1. Spanish mackerel nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing vertical line gear in the Western Gulf of Mexico.

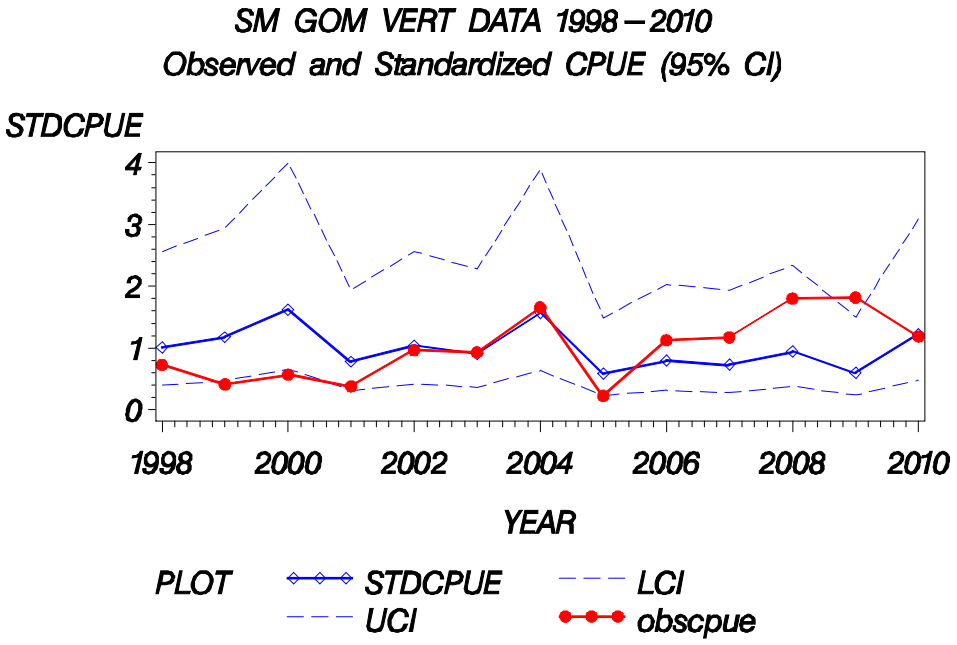


Figure 2. Annual trend in the nominal CPUE for 1998-2010 Spanish mackerel commercial fishing vertical line gear in the Western Gulf of Mexico.

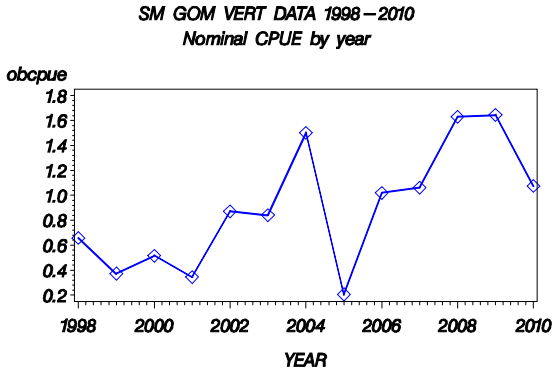
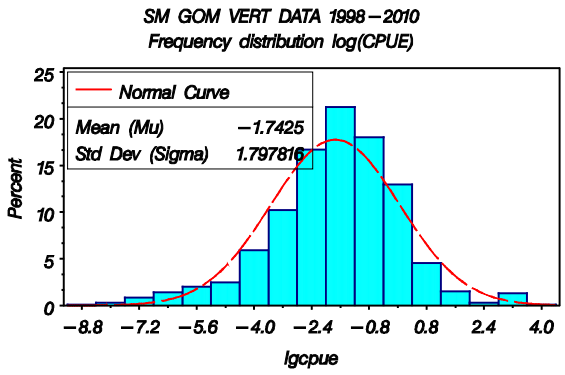


Figure 3. Diagnostic plots for the lognormal component of vertical line of Spanish mackerel in the Western Gulf of Mexico, 1998-2010 gear model: **(i)** the frequency distribution of log(CPUE) on positive trips, **(ii)** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

i.



ii.

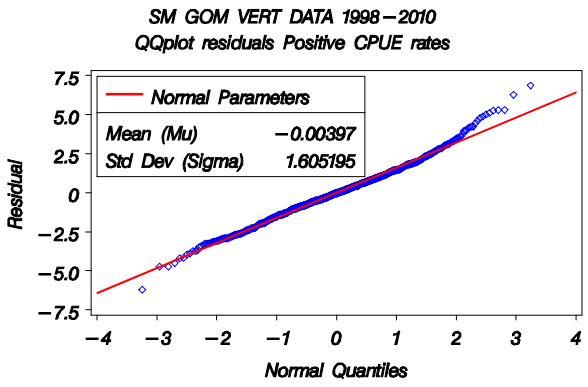
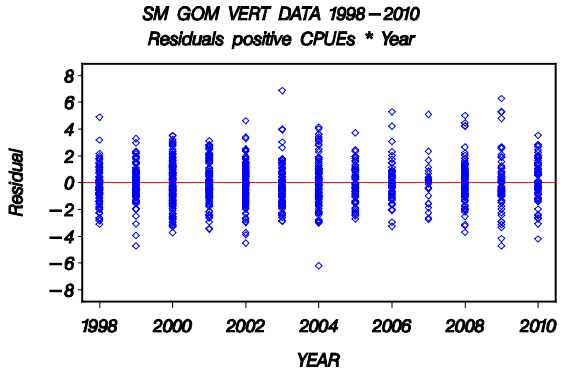
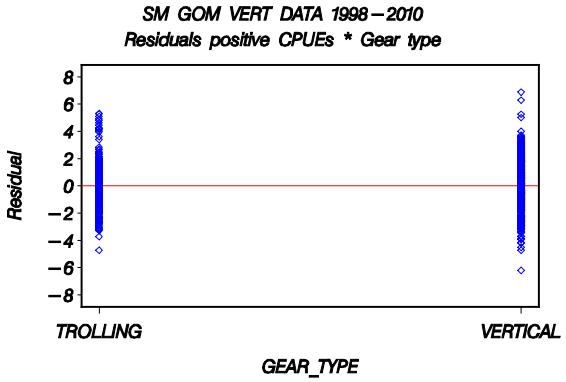


Figure 4. Diagnostic plots for the lognormal component of vertical line of Spanish mackerel in the Western Gulf of Mexico, 1998-2010 gear model: **(i)** the Chi-Square residuals by year; **(ii)** the Chi-Square residuals by Gear type; **(iii)** the Chi-Square residuals by days at sea and **(iv)** the Chi-Square residuals by the number of crew.

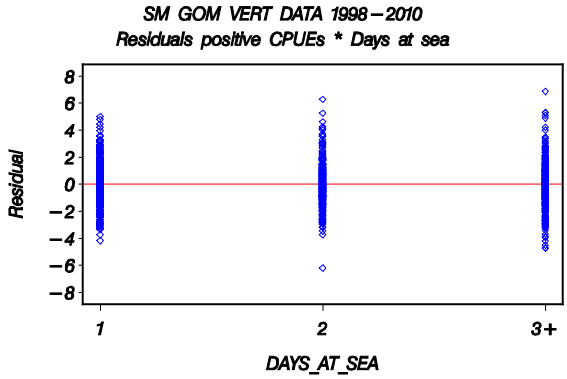
i.



ii.



iii.



iv.

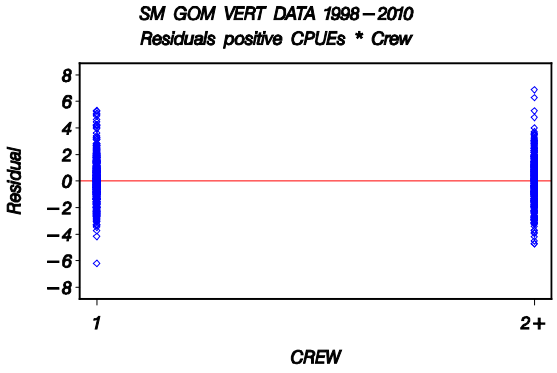


Figure 5. Western Gulf of Mexico only index plotted with Gulf-wide CFLP vertical line index .

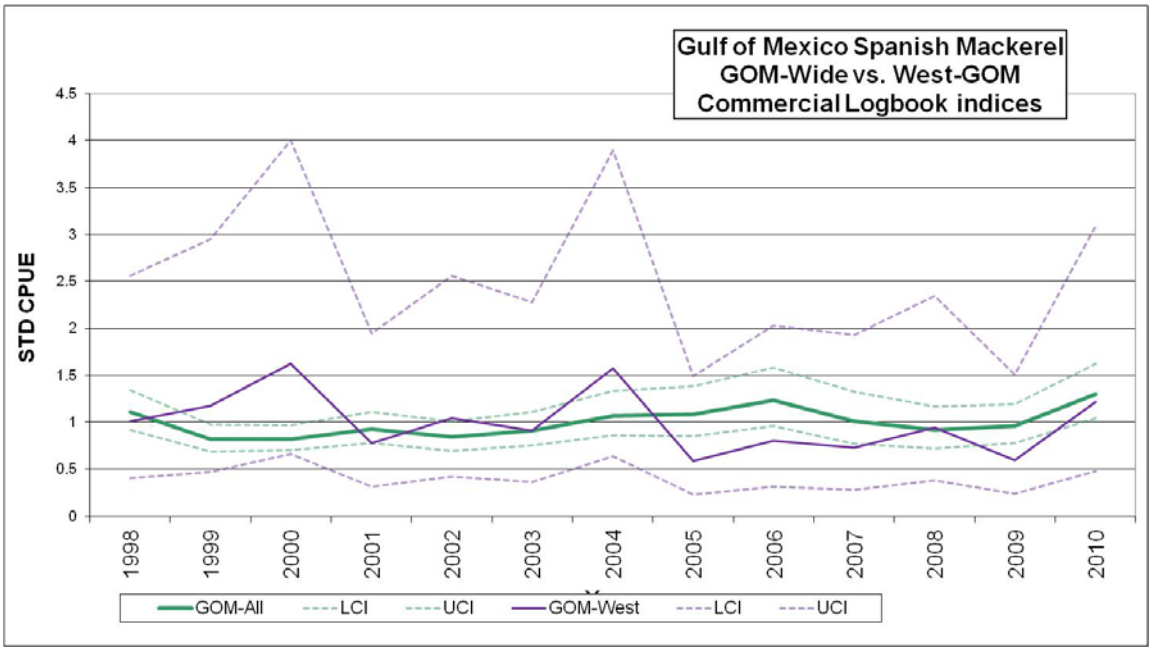


Figure 6. CFLP statistical grid area map