United States Commercial Longline Vessel Standardized Catch Rates of Golden and Blueline Tilefish in the Gulf of Mexico, 1992-2009

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Introduction

Handline, electric reel (bandit rig), and longline landings and fishing effort of commercial vessels operating in the Gulf of Mexico and U.S. south Atlantic have been reported to the National Marine Fisheries Service (NMFS) through the Coastal Fisheries Logbook Program (CFLP, conducted by the NMFS Southeast Fisheries Science Center). The program collects landings and effort data by fishing trip from vessels that are federally permitted to fish in a number of fisheries managed by the Gulf of Mexico and South Atlantic Fishery Management Councils. The coastal logbook program began in 1990 with the objective of a complete census of coastal fisheries permitted vessel activity, with the exception of Florida, where a 20% sample of vessels was selected to report. Beginning in 1993, reporting in Florida was increased to include all vessels permitted for Federally managed coastal fisheries.

The CFLP available catch per unit effort (CPUE) data were used to construct separate standardized abundance indices for golden and blueline tilefish. Indices were constructed using data reported from commercial bottom longline trips in the Gulf of Mexico. Other gear accounted for a very small percentage of total commercial landings (<13% of blueline tilefish, 1% of golden tilefish). Although the coastal logbook data series began in 1990, very few or no positive tilefish trips were reported during 1990-91. Golden tilefish data were sufficient to construct an index of abundance including the years 1992-2009. Data for constructing a blueline tilefish index were available for the years 1993-2009.

Methods

Available Data

For each fishing trip, the coastal logbook database included a unique trip identifier, the landing date, fishing gear deployed, areas fished (Figure 1), number of days at sea, number of crew, gear specific fishing effort, species caught and weight of the landings. Fishing effort data available for longline gear included number of sets and number of hooks fished per set. 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 possible; therefore, only trips which reported one area (i.e. statarea, as defined below) and one gear fished were included in these analyses.

Data were further restricted to include only those trips with landings and effort data reported within 45 days of the completion of the trip. Approximately 67 percent of longline trips were retained for analyses. Reporting delays beyond 45 days (some reporting delays were longer than one year) likely resulted in less reliable effort data. Landings data may be reliable even with lengthy reporting delays if trip ticket reports were referenced by the reporting fisher.

Clear outliers in the data, e.g. values falling outside the 99.5 percentile of the data, were excluded from the analyses. These included longline data from trips reporting more than 24 sets per day, more than 3,000 hooks per set, fewer than 18 hooks per set, or longline lengths more than 20 miles or less than 1 mile. Data from trips that reported crews of more than 6 or trips of more than 20 days at sea were also excluded from the analyses.

Management measures, specifically closed seasons, required that additional data be excluded from the analyses. Closed seasons occurred yearly beginning in 2005 due to quota restrictions. Data from closed seasons were excluded from the analyses. No minimum size or trip limit restrictions were in effect for either species of tilefish during the years

Golden and blueline tilefish trips were identified separately using a data subsetting technique (modified from Stephens and MacCall, 2004) intended to restrict the data set to trips with fishing effort in tilefish habitat. Such an approach was necessary because fishing location was not reported to the CFLP at a spatial scale adequate to identify targeting based upon the habitat where the fishing occurred. The modified Stephens and MacCall method was an objective approach in which a logistic regression was applied to estimate the probability that tilefish could have been encountered given the presence or absence of other species reported from the trip. As a function of the species reported from a trip, a score was assigned to the trip and that score was converted into the probability of observing tilefish. Trips with scores above a critical value were included in the CPUE analysis. That critical value was set at the score that minimized the number of predictions of tilefish occurring when the species was actually absent (false positives) while also minimizing incorrect predictions of tilefish absence when the species was actually present (false negatives).

For each species, targeted trips were identified independently for the eastern Gulf of Mexico (statistical areas 2-7) and the western Gulf (statistical areas 8-21). This east-west partitioning approximately matched the demarcation line at Cape San Blas where longline gear is restricted to 20 fathoms or greater depths (east) and 50 fathoms or greater depths (west). Prior to identifying targeted trips, data from areas 1 and 12 were excluded from the analyses of both species, due to small sample sizes from those areas. Data from areas 18-21 were excluded from the blueline tilefish analysis, also due to small sample size. For each region, eastern and western Gulf of Mexico, those species that were reported from one percent or more of all longline trips were included in the data subsetting analyses. Figure 2A-D provide species-specific regression coefficients. The magnitude of the coefficients indicates the predictive impact of each species.

Index Development

Longline catch rate was calculated as weight of tilefish per hook fished (hours fished were not consistently reported for longline gear to the CFLP and could not be reliably included in the analysis):

CPUE = pounds of tilefish/(number of sets*number of hooks per set)

Eight factors were considered as possible influences on longline proportion of trips that landed tilefish and on the catch rate of tilefish. An additional factor, number of hooks fished, was examined for its affect on the proportion of positive trips. In order to develop a well balanced sample design it was necessary to define categories within some of the factors examined:

Golden tilefish

Factor	Levels	Value
Year	18	1992-2009
Season	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	9	Stat areas 2-4, 5, 6-7, 8, 9, 10-11, 13-15, 19-21 see Figure 1
Longline length (ll_length)*	4	1-2.9, 3-4.9, 5-5.9, 6+ miles
Days at sea (seadays)*	4	1-5, 6-8, 9-11, 12-20 days
Crew (crew1)*	3	1-2, 3, 4-6 crew members
Distance between hooks (hk_dist1)*	3	<21.2, 21.2-31.5, >31.5 feet
Hooks fished (hks_fished)*[1]	4	<8,000; 8,000-17,000; 17,001-32,300; 32,301+ hooks

* Names in parentheses appear in some figures and tables.
[1] Hooks fished was examined only for the proportion positive analyses.

Blueline tilefish

Factor	Levels	Value
Year	17	1993-2009
Season	4	Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec
Subregion	5	Statistical areas 2-3, 4, 5, 6-7, 8-17 see Figure 1.
Longline length (ll_length)*	2	<6, 6+ miles
Days at sea (seadays)*	2	1-11, 12-20 days
Crew (crew1)*	3	1-2, 3, 4-6 crew members
Distance between hooks (hk_dist1)*	2	<26 feet, 26+ feet
Hooks fished (hks_fished)*[1]	2	<25,000, 25,000+ hooks

* Names in parentheses appear in some figures and tables.
[1] Hooks fished was examined only for the proportion positive analyses.

The delta lognormal model approach (Lo et al. 1992) was used to construct standardized indices of abundance. This method combines separate general linear model (GLM) analyses of the proportion of successful trips (trips that landed tilefish) and the catch rates on successful trips to construct a single standardized CPUE index. 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).

For each GLM analysis 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. During the analysis 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 longline data was calculated as: log(CPUE)=ln(pounds of tilefish/hooks fished). 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 ≥1%. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model.

Once a set of fixed factors was identified, the influence of the YEAR*FACTOR interactions were examined. YEAR*FACTOR interaction terms were included in the model as random effects. 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).

The final delta-lognormal model was fit using a SAS macro, GLIMMIX (Russ Wolfinger, SAS Institute). To facilitate visual 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 for each species were:

Golden tilefish:

PPT = Subregion + Days at Sea + Year

LOG(CPUE) = Subregion + Days at Sea + Year + Subregion*Year + Days at Sea*Year + Subregion*Days at Sea

In the proportion positive analysis, Year did not meet the criteria for inclusion in the final model, but was included in the final binomial portion of the model. No two-way interactions involving Year were tested for inclusion in the final binomial portion of the model. The linear regression statistics and analysis of the mixed model formulations of the final models are summarized in Table 1.

Blueline tilefish:

PPT = Subregion + Year

LOG(CPUE) = Subregion + Distance Between Hooks + Year + Distance Between Hooks*Year

In the proportion positive analysis, Year did not meet the criteria for inclusion in the final model, but was included in the final binomial portion of the model. The two-way interactions Subregion*Year was not tested for inclusion in the final binomial portion of the model. The linear regression statistics of the final GLM models are summarized in Table 2.

Relative nominal CPUE, number of trips, proportion positive trips, and relative abundance indices are provided in Tables 3 and 4 for the golden tilefish and blueline tilefish models. The delta-lognormal abundance indices developed for each species, with 95% confidence intervals, are shown in Figures 3 and 4.

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 5-8 (golden tilefish) and Figures 9-12 (blueline tilefish). Those diagnostic plots indicate that the fit of the data to the lognormal and binomial models was acceptable. There were some outliers among these data, however, and the frequency distribution of log(CPUE) data for each species were slightly 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 golden tilefish trips ranged from approximately 64 to 86% and were within the acceptable range required for the analysis. Blueline tilefish percent positive trips were also within the range appropriate for the analysis (48-82%).

Golden tilefish standardized catch rates for longline vessels had no clear trend over much of the time series. CPUE increased through 1994, but no clear trend was apparent from 1994 through 2002. CPUE decreased in 2003 then generally increased from 2003 to 2009. Coefficients of variation (CV) were in the range 0.33-0.37 except for the first two years of the series when CVs were slightly larger. Those higher initial CVs may have been due to smaller sample sizes (i.e. sampling error) during the period of 20 percent reporting in Florida.

Blueline tilefish CPUE also increased during the first three years of the time series (1993-1995) with no clear trend from 1995-2003. Yearly standardized CPUE increased from 2003 to 2008, but decreased again in 2009. CVs and confidence intervals for blueline tilefish were much larger than were found in the golden tilefish analysis. CPUE appears much more variable in the blueline tilefish data than was observed in the golden tilefish data. Smaller sample size cannot fully explain that greater CPUE variability, although sample size may play a role. The large confidence intervals around the blueline tilefish index suggest that there may be no trend in mean yearly CPUE over the time series or that any trend cannot be detected from the available data.

Acknowledgements

Thanks to Drs. John Quinlan and John Walter for the valuable discussions, advice, and help regarding methods for identifying tilefish trips.

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.

Stephens, A. and A. McCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fisheries Research 70:299-310.

Table 1. Linear regression statistics for the GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for golden tilefish in the Gulf of Mexico for vessels reporting longline gear landings 1992-2009. Analysis of the mixed model formulations of the positive trip model (**C**). 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.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	17	546	29.19	1.72	0.0329	0.0362
subregion	8	546	415.86	51.98	<.0001	<.0001
seadays	3	546	54.99	18.33	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	17	51	15.44	0.91	0.5635	0.5683
subregion	8	134	171.58	21.45	<.0001	<.0001
seadays	3	51	35.14	11.71	<.0001	<.0001
*subregion*seadays*	24	2396	57.97	2.42	0.0001	0.0001

C.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
subregion + seadays + year	10100.8	10102.8	10108.6	-	-
*subregion + seadays + year + subregion*year*	10056.3	10060.3	10066.5	44.5	<0.0001
*subregion + seadays + year + subregion*year + seadays*year*	10041.5	10047.5	10056.7	14.8	0.0001
*subregion + seadays + year + subregion*year + seadays*year + subregion*seadays*	9993.6	9999.6	10008.8	47.9	<0.0001

Table 2. Linear regression statistics for the GLM models on proportion positive trips (**A**) and catch rates on positive trips (**B**) for blueline tilefish in the Gulf of Mexico for vessels reporting longline gear landings 1993-2009. Analysis of the mixed model formulations of the positive trip model (**C**). 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.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	16	63	26.06	1.63	0.0533	0.0872
subregion	4	63	150.73	37.68	<.0001	<.0001

B.

Type 3 Tests of Fixed Effects

Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*
year	16	16	18.23	1.14	0.3105	0.3986
subregion	4	1049	166.12	41.53	<.0001	<.0001
hk_dist1	1	16	14.48	14.48	0.0001	0.0016

C.

Catch Rates on Positive Trips	*-2 REM Log likelihood*	*Akaike's Information Criterion*	*Schwartz's Bayesian Criterion*	*Likelihood Ratio Test*	*P*
subregion + hk_dist1 + year	4010.0	4012.0	4017.0	-	-
*subregion + hk_dist1 + year + hk_dist1*year*	3995.7	3999.7	4002.8	14.3	0.0002

Table 3. Longline relative nominal CPUE, number of trips, proportion positive trips, and standardized abundance index for golden tilefish (1992-2009) in the Gulf of Mexico.

YEAR	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1992	0.696285	72	0.638889	0.511599	0.1763	1.484593	0.572795
1993	0.576969	103	0.699029	0.784492	0.342475	1.796997	0.432865
1994	1.350587	195	0.815385	1.137181	0.595081	2.173119	0.332482
1995	1.037016	229	0.820961	1.109442	0.576145	2.136373	0.336618
1996	0.924305	146	0.863014	0.881585	0.432639	1.7964	0.367483
1997	1.275656	228	0.767544	0.981243	0.492683	1.954276	0.354954
1998	1.295589	209	0.76555	1.145312	0.581097	2.257352	0.349257
1999	1.206708	236	0.758475	1.224067	0.63577	2.356736	0.336534
2000	1.04836	294	0.782313	0.829545	0.424442	1.621294	0.344678
2001	1.108935	255	0.815686	1.019424	0.526665	1.97322	0.339424
2002	0.97124	251	0.812749	0.900457	0.457502	1.772284	0.348499
2003	1.103007	277	0.823105	0.58315	0.286881	1.185383	0.366142
2004	0.537684	163	0.760736	0.71944	0.349189	1.482272	0.37356
2005	0.676155	158	0.727848	0.911633	0.444968	1.867719	0.370463
2006	0.85811	161	0.689441	1.078831	0.5349	2.175879	0.361849
2007	1.279	128	0.859375	1.642863	0.841468	3.207487	0.344104
2008	0.823009	154	0.701299	1.030535	0.493889	2.150288	0.380554
2009	1.231386	125	0.728	1.5092	0.746835	3.049782	0.362911

Table 4. Longline relative nominal CPUE, number of trips, proportion positive trips, and relative abundance index for tilefish (1993-2009) in the Gulf of Mexico.

Year	Relative Nominal CPUE	Trips	Proportion Successful Trips	Standardized Index	Lower 95% CI (Index)	Upper 95% CI (Index)	CV (Index)
1993	0.498682	51	0.490196	0.437784	0.026067	7.35235	2.512461
1994	0.345656	106	0.603774	0.619062	0.065784	5.825683	1.585217
1995	1.542235	94	0.606383	0.803995	0.095155	6.793211	1.456823
1996	0.935702	46	0.478261	0.505964	0.030113	8.501312	2.513407
1997	0.936111	127	0.677165	0.978834	0.146929	6.520939	1.207218
1998	0.825907	97	0.731959	1.100601	0.165933	7.300052	1.202992
1999	0.636485	84	0.595238	0.51631	0.040921	6.514403	1.996501
2000	1.09752	114	0.675439	1.409594	0.259333	7.661797	1.02337
2001	0.569687	126	0.595238	0.472304	0.039849	5.597843	1.900127
2002	0.87944	85	0.6	0.914954	0.108287	7.730744	1.456823
2003	0.769957	128	0.640625	0.541005	0.055665	5.258001	1.625787
2004	0.969509	119	0.647059	0.849812	0.107124	6.741535	1.386385
2005	1.179599	92	0.641304	1.091026	0.136287	8.734088	1.396333
2006	1.373769	119	0.731092	1.451889	0.272369	7.739445	1.006974
2007	1.63564	74	0.72973	1.864569	0.356819	9.743356	0.990414
2008	1.641751	102	0.823529	2.280721	0.568797	9.145065	0.787104
2009	1.16235	89	0.741573	1.161576	0.185036	7.29185	1.150989

Figure 1. Coastal Logbook defined fishing areas.

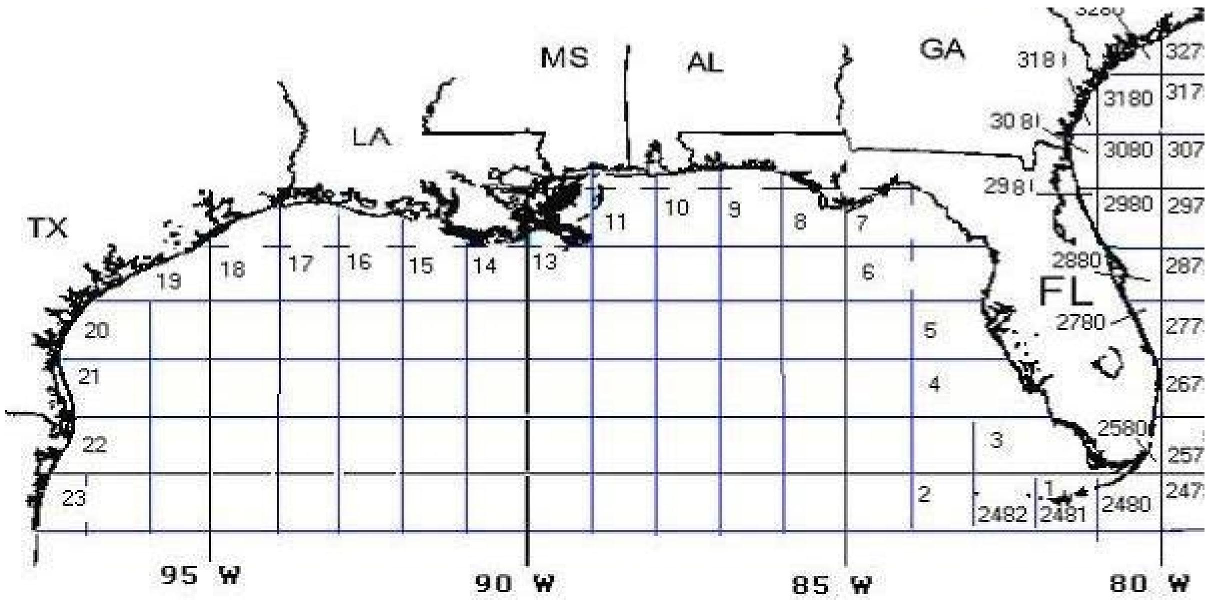
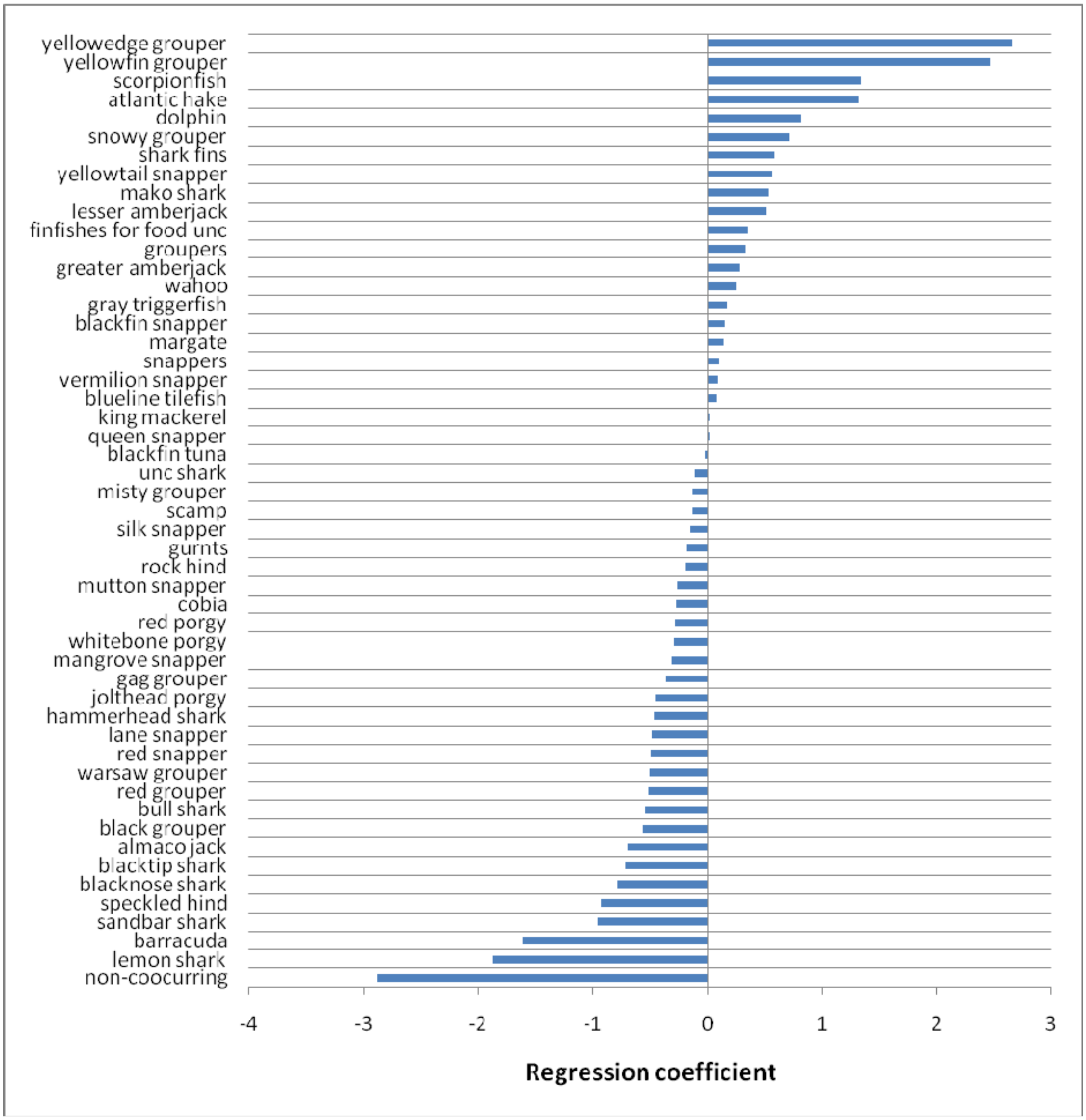
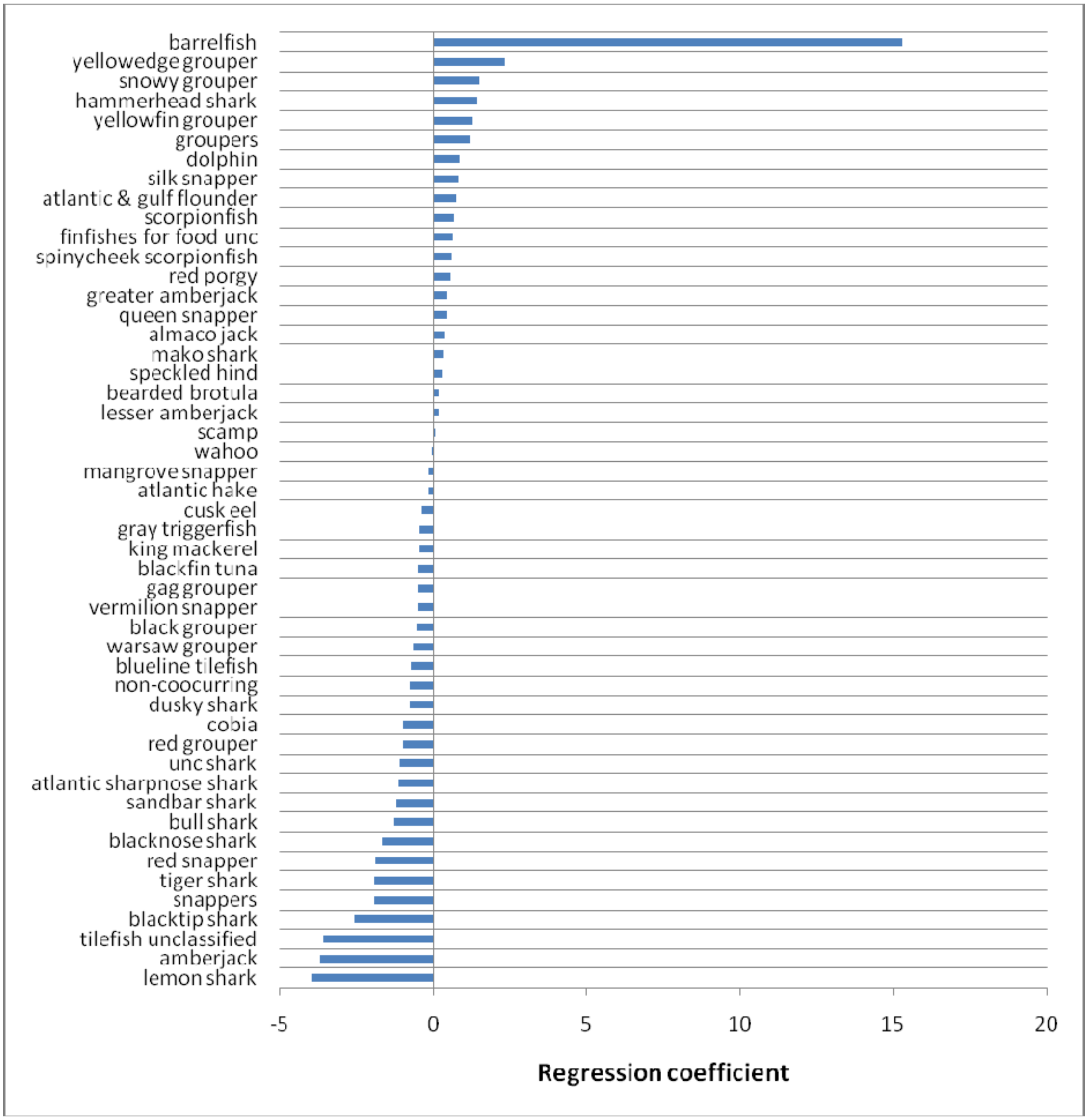


Figure 2. Regression coefficients from the Stephens & MacCall analyses. Positive coefficients signify species that had positive associations with the target species. The magnitude of the coefficients indicates the predictive impact of each species. The value for "non-coocurring" is the regression intercept and denotes the probability a trip was fishing in the target species' habitat, but did not report any of the listed species. Species included were reported on at least one percent of longline trips in the eastern or western Gulf of Mexico.

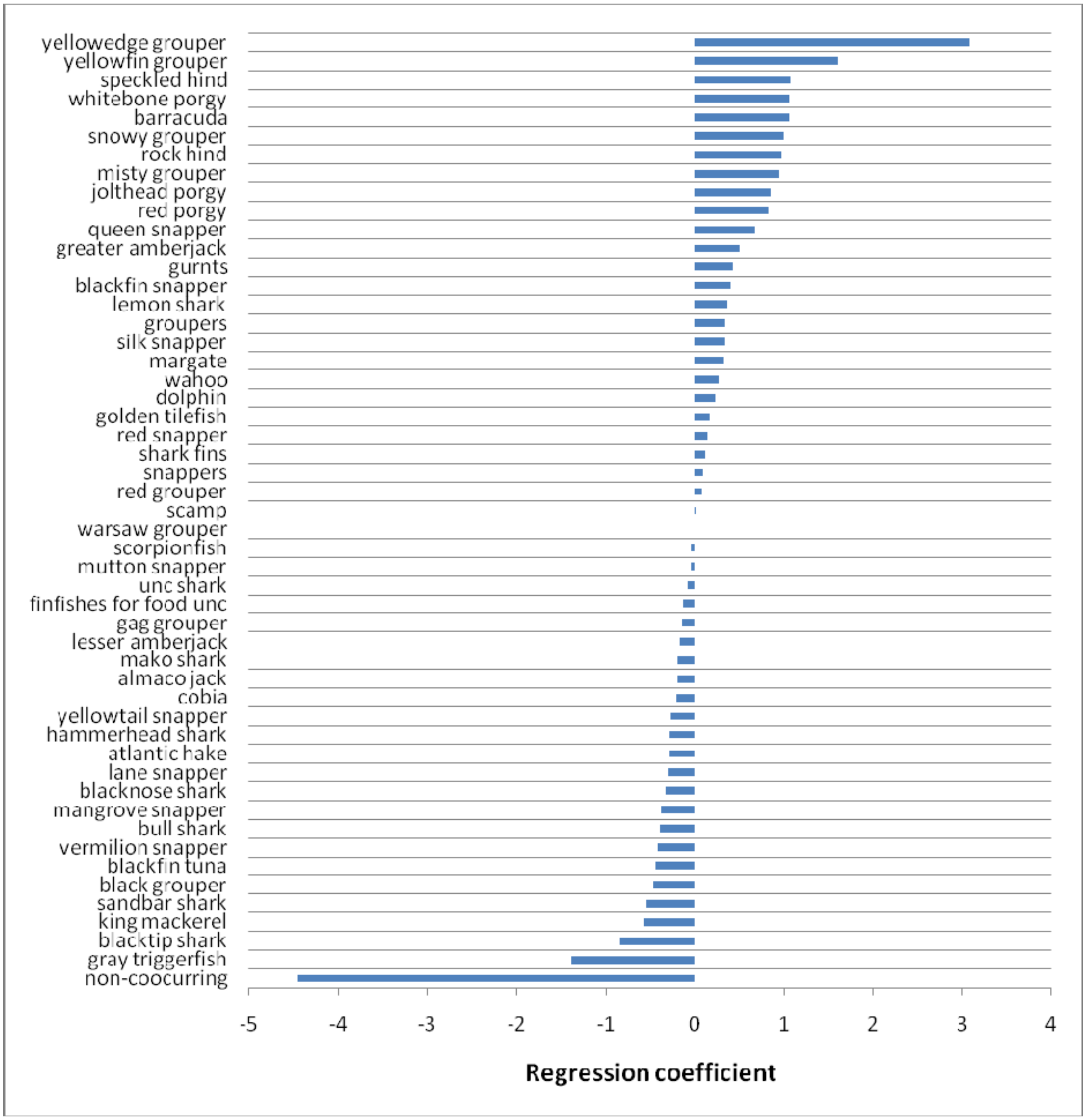
A. Golden tilefish eastern Gulf of Mexico longline



B. Golden tilefish western Gulf of Mexico longline



C. Blueline tilefish eastern Gulf of Mexico longline



D. Blueline tilefish western Gulf of Mexico longline

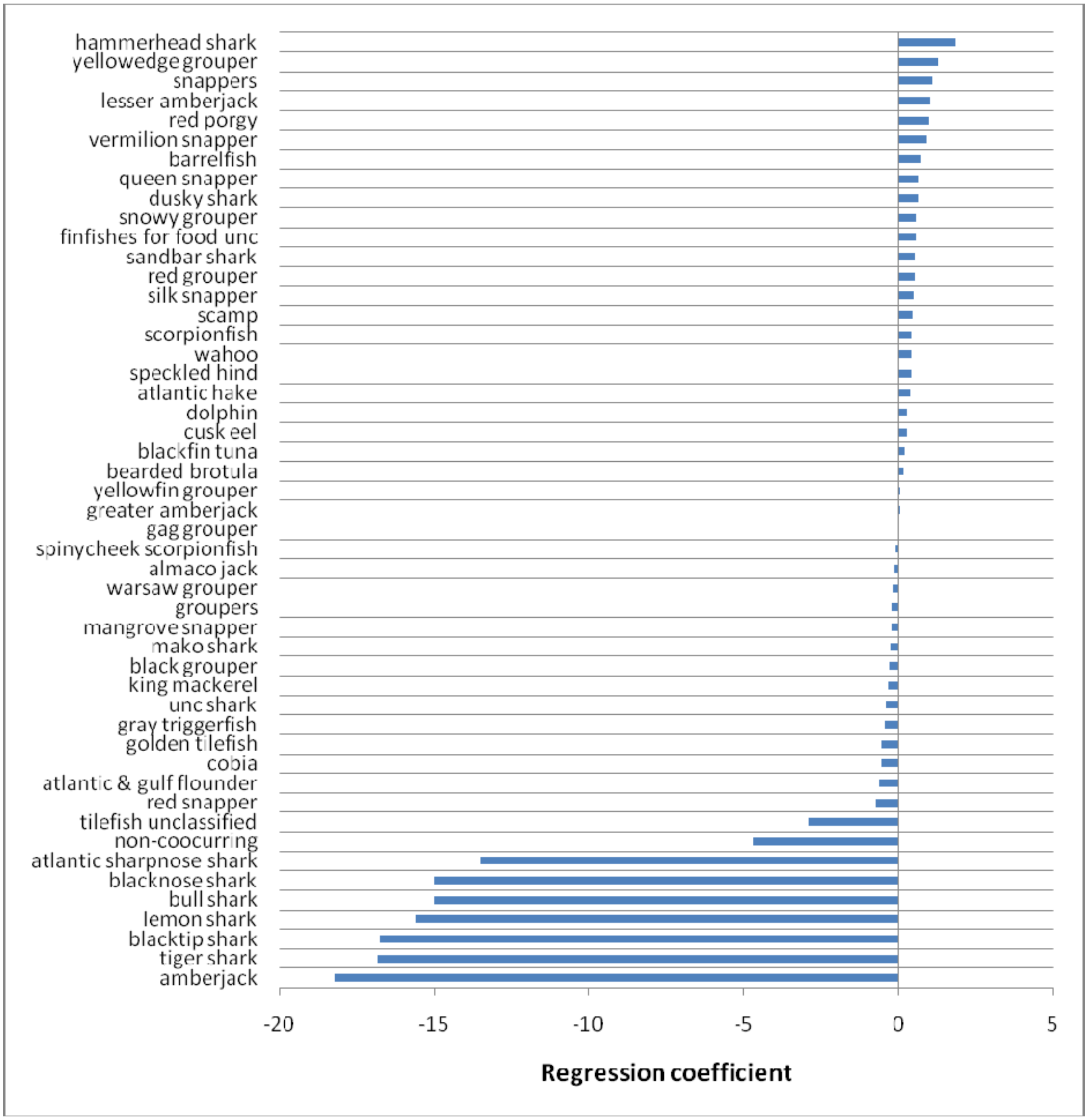


Figure 3. Golden tilefish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing longline gear in the Gulf of Mexico.

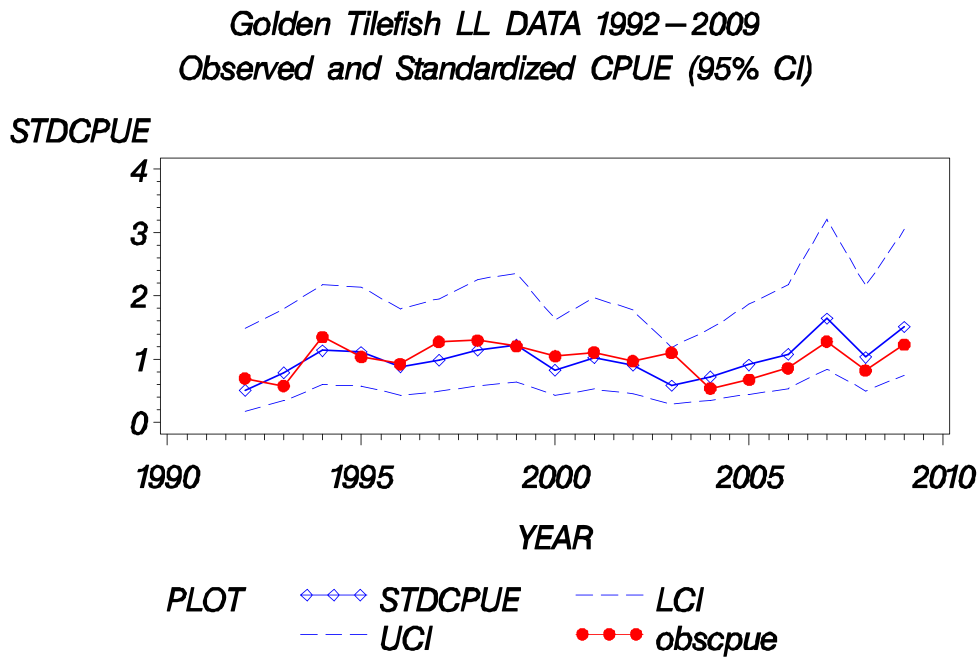


Figure 4. Blueline tilefish nominal CPUE (solid circles), standardized CPUE (open diamonds) and upper and lower 95% confidence limits of the standardized CPUE estimates (dashed lines) for vessels fishing longline gear in the Gulf of Mexico.

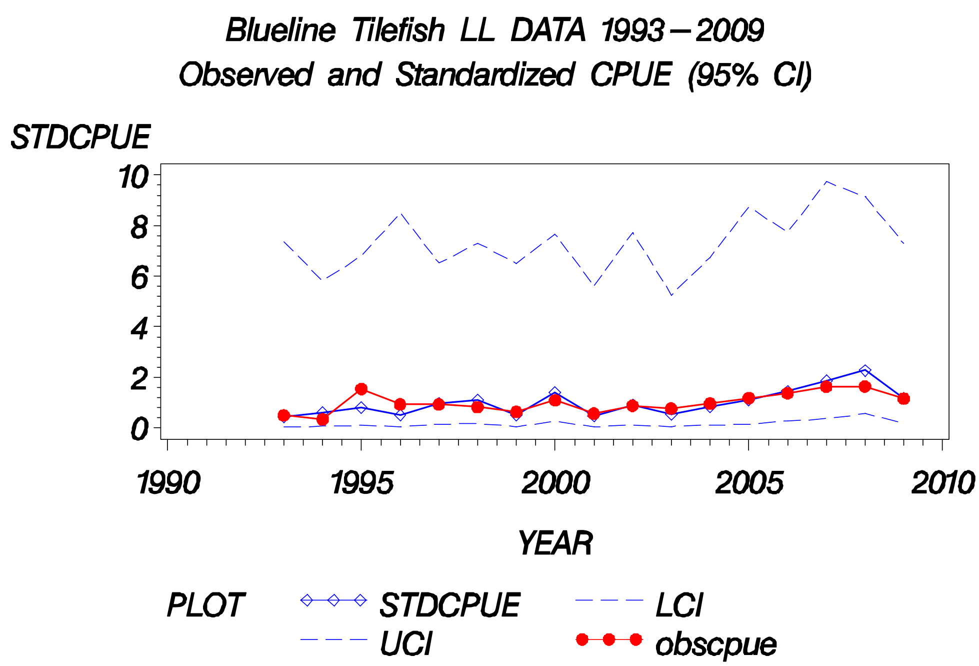
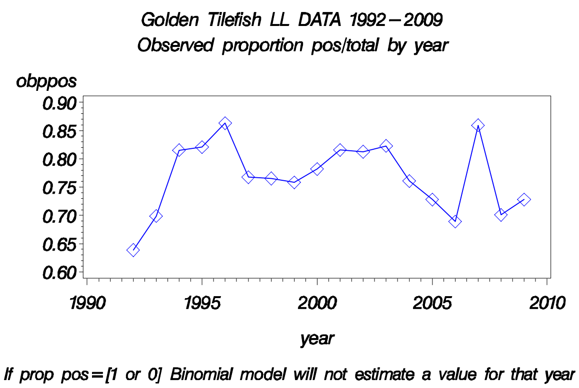


Figure 5. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE of the Gulf of Mexico 1992-2009 golden tilefish commercial longline gear data.

A.



B.

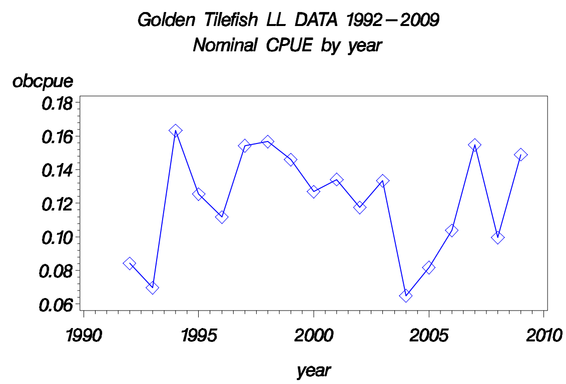
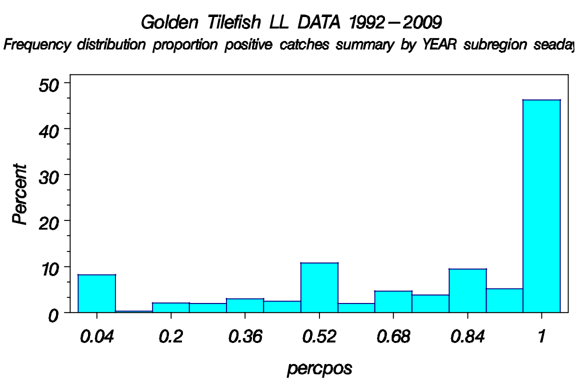
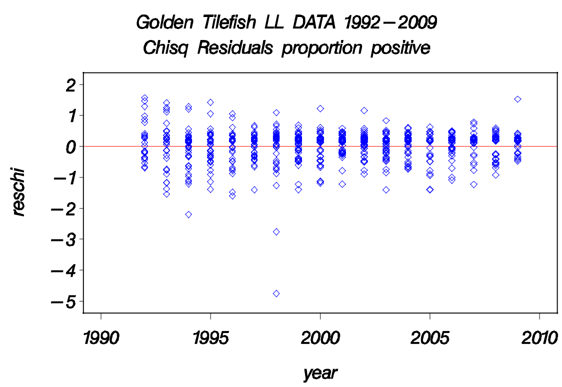


Figure 6. Diagnostic plots for the binomial component of the Gulf of Mexico 1992-2009 golden tilefish commercial longline gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; **C**. the Chi-Square residuals by subregion; and **D**. the Chi-Square residuals by days at sea.

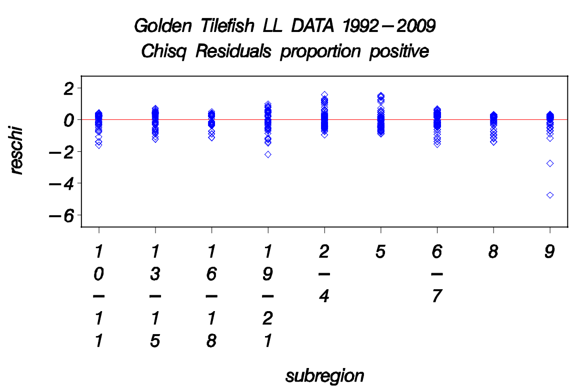
A.



B.



C.



D.

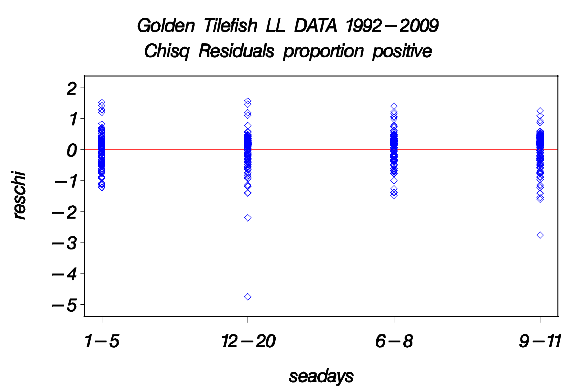
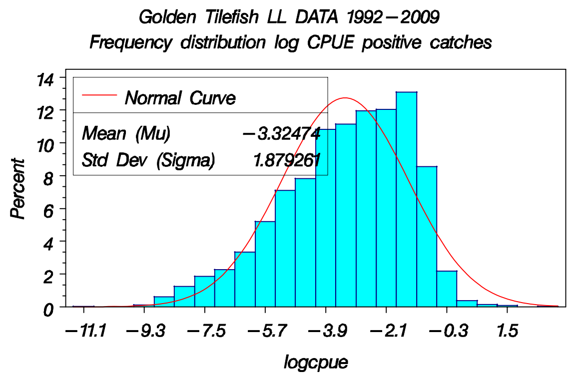


Figure 7. Diagnostic plots for the lognormal component of the Gulf of Mexico 1992-2009 golden tilefish commercial longline gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

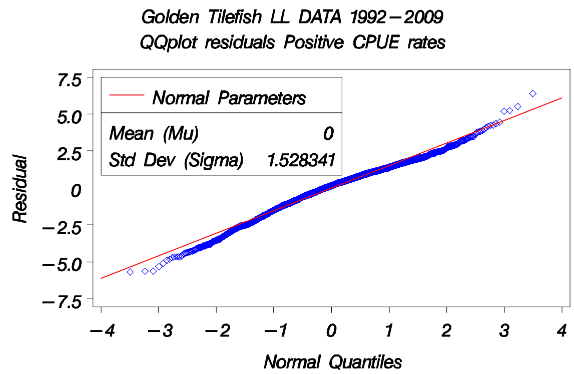
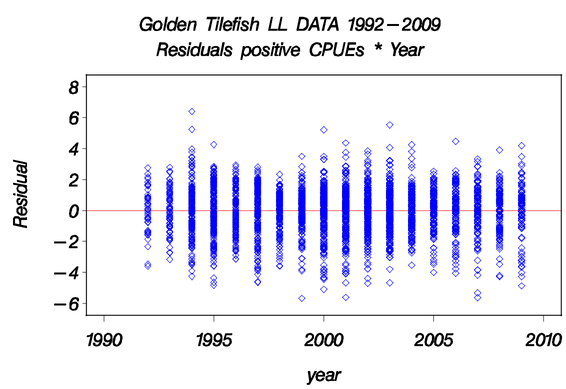
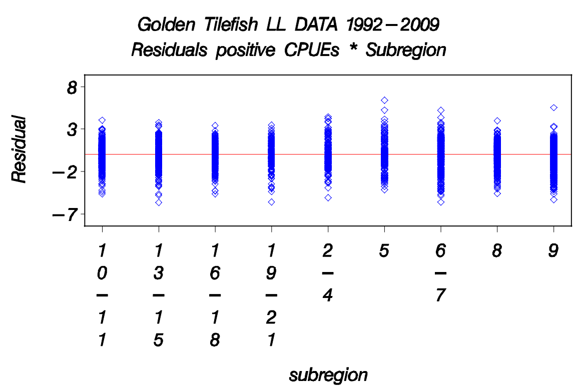


Figure 8. Diagnostic plots for the lognormal component of the Gulf of Mexico 1992-2009 golden tilefish commercial longline gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by subregion; and **C**. the Chi-Square residuals by days at sea.

A.



B.



C.

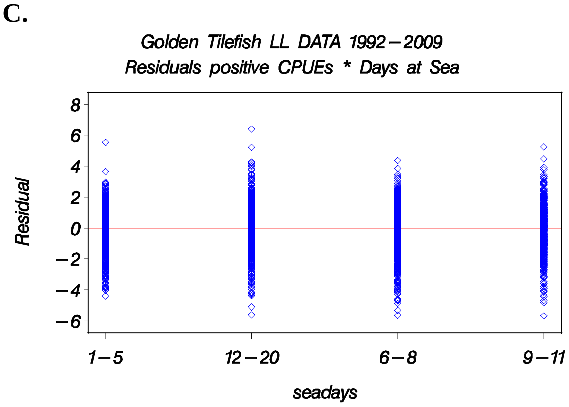
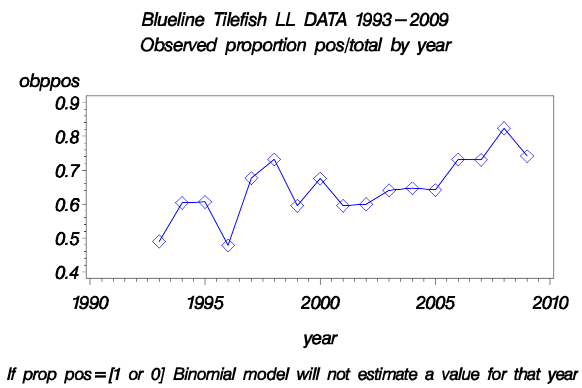


Figure 9. Annual trend in **A.** the proportion of positive trips and **B.** nominal CPUE of the Gulf of Mexico 1993-2009 blueline tilefish commercial longline gear data.

A.



B.

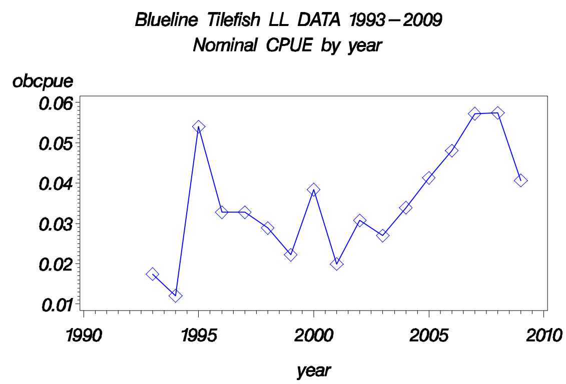
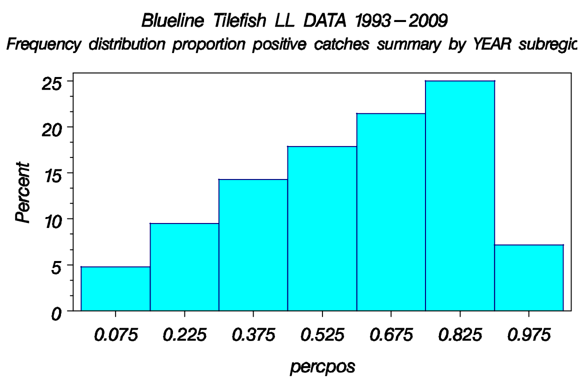
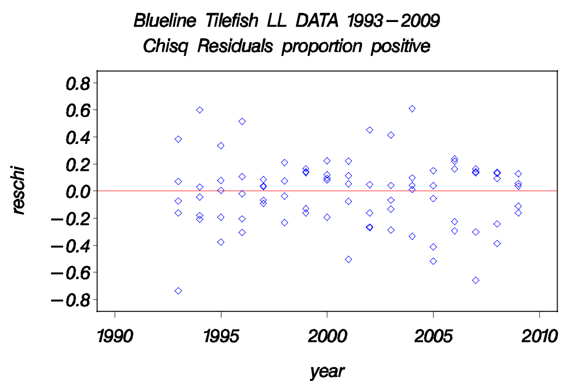


Figure 10. Diagnostic plots for the binomial component of the Gulf of Mexico 1993-2009 blueline tilefish commercial longline gear model: **A**. the frequency distribution of the proportion positive trips; **B**. the Chi-Square residuals by year; and **C**. the Chi-Square residuals by subregion.

A.



B.



C.

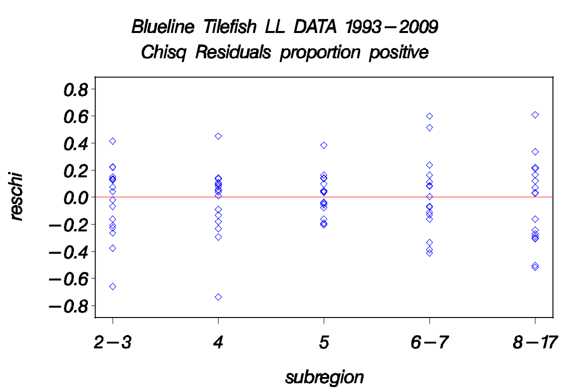
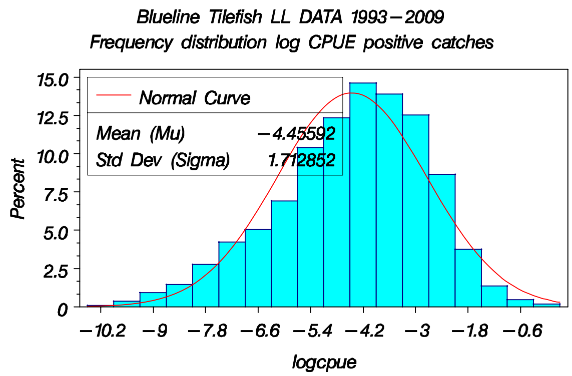


Figure 11. Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2009 blueline tilefish commercial longline gear model: **A.** the frequency distribution of log(CPUE) on positive trips, **B.** the cumulative normalized residuals (QQ-Plot) from the lognormal model. The red line is the expected normal distribution.

A.



B.

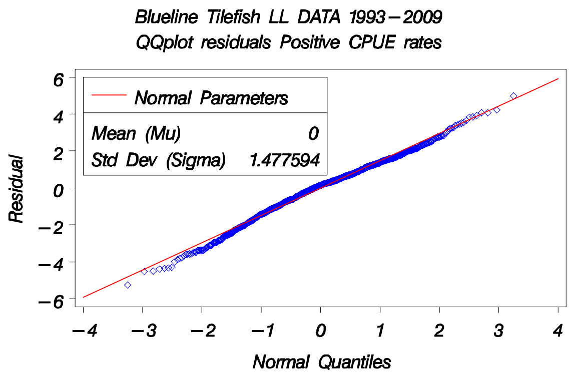
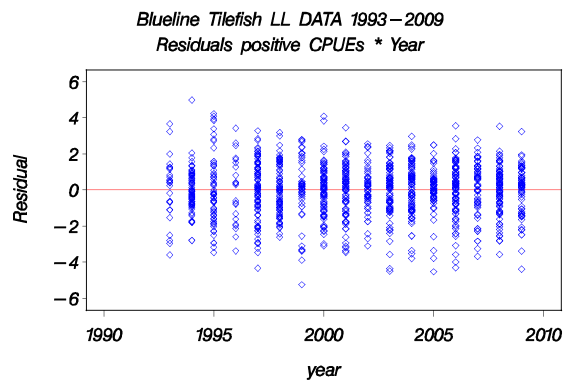
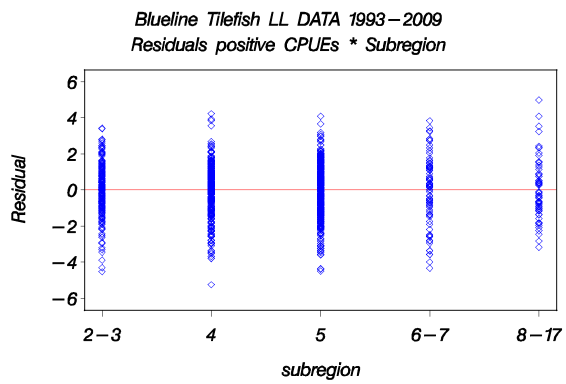


Figure 12. Diagnostic plots for the lognormal component of the Gulf of Mexico 1993-2009 blueline tilefish commercial longline gear model: **A**. the Chi-Square residuals by year; **B**. the Chi-Square residuals by subregion; and **C**. the Chi-Square residuals by distance between hooks.

A.



B.



C.