Standardized Catch Rate Indices for Red Snapper (*Lutjanus campecanus*) during 1993-2006 by the U.S. Gulf of Mexico Vertical Line Fishery

Gulf of Mexico Branch, Sustainable Fisheries Division

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Keywords

Catch, fishing effort, catch-per-unit-effort (CPUE), commercial fisheries, Vertical Line, Red Snapper, Individual Fishing Quota (IFQ)

Abstract

Standardized catch rate indices of relative abundance (catch-per-unit-effort; CPUE) were developed for the commercial Vertical Line fishery in the U.S. Gulf of Mexico for the SEDAR 74 Research Track Red Snapper stock assessment. An individual fishing quota (IFQ) system began January 1, 2007 for the commercial Red Snapper fishery, which changed how the fishery operates. A Pre-IFQ Vertical Line index was developed using a delta-lognormal generalized linear model for the years 1993 to 2006. A Post-IFQ Vertical Line index was not developed because a functional relationship between catch-per-unit-effort data and abundance is unknown in the presence of an IFQ system. All indices in this document use data from the Coastal Fisheries Logbook Program and were developed following standardization methodologies consistent with previous analyses for other Gulf snapper species.

Introduction

The National Marine Fisheries Service (NMFS) collects information on catch and fishing effort from the commercial fishing industry in the Southeastern Region through the Southeast Fisheries Science Center's Coastal Fisheries Logbook Program (CFLP). Individuals who carry commercial federal fishing permits are required to provide information on their landings and fishing effort for each trip that they take. The CFLP in the U.S. Gulf of Mexico (GOM) began in 1990 with the objective of a complete census of reef fish fishery permitted vessel activity. Florida was the exception, where a 20% sample of vessels was targeted. Beginning in 1993, the sampling in Florida was increased to require reports from all vessels permitted in the reef fish fishery and a complete census was obtained.

Using the catch and effort data available through this program, indices of relative abundance for Red Snapper were developed for the Vertical Line fishery from the U.S. GOM following standardization procedures used for other Gulf snapper species. Given the unknown impact on red snapper catch rates resulting from the implementation of the Red Snapper Individual Fishing Quota (IFQ) program in 2007, indices were only developed for the pre-IFQ time period (through 2006). The IFQ program aimed to reduce overcapacity of the snapper fishing fleet, increase harvesting efficiency, and eliminate the race to fish. Additional information on the IFQ program can be found at the NMFS's Southeast Regional Office webpage on limited access programs.

Materials and Methods

Data Source

The CFLP collects data on the catch and effort for individual commercial fishing trips. Reported information includes a unique trip identifier, the landing date, fishing gear deployed, areas fished (equivalent to NMFS shrimp statistical grids; **Figure 1**), number of days at sea, number of crew, gear specific fishing effort, species caught and whole weight of the landings. Fishing effort data available for handline and electric reel (bandit gear) trips includes the number of lines fished, total hours fished, and the number of hooks per line. Fishing effort data available for longline trips includes the number of sets and number of hooks per set.

Logbook data were used to characterize abundance trends of Red Snapper in the U.S. GOM. Catch-per-unit-effort (CPUE) was calculated on an individual trip basis for each fishery. Electric reel (bandit) and manual handline were combined into a single Vertical Line fishery as they are often reported together on the same trip, or one gear may be reported in place of the other, and as a result, it is not possible to apportion fishing effort separately by electric or manual handline. For the Vertical Line fishery, CPUE for each trip was defined as the whole weight of Red Snapper landed on a trip divided by the effort, where effort was the product of the number of lines fished, the hooks per line, and the total hours fished.

Data Filtering

General data exclusions for analyses using CFLP data were as follows:

1. Multiple areas fished may be recorded for a single fishing trip. In such cases, assigning catch and effort to specific locations was not possible; therefore, only trips in which one area fished was reported were included.

2. Multiple fishing gears may be recorded for a single fishing trip. In such cases assigning catch and effort to a particular gear type was not possible. Trips fishing multiple gears were excluded in these analyses.

3. Logbook reports submitted 45 days or more after the trip completion date were excluded due to the lengthy gap in reporting time.

4. Trips that fell outside the 99.5th percentile were considered to represent mis-reported data or data entry errors and were excluded for the following variables: number of lines for Vertical Line or number of sets for Longline, number of hooks per line, the hours fished per day, the Longline length, number of hook hours for Vertical Line, the number of days at sea (trip duration), and the number of crew members. Vertical Line trips with reported fishing more than 24 hours per day were also excluded.

5. Seasonal closures and regulatory closures have been employed to manage the commercial snapper fishery. The dataset was restricted to time periods for which fishing on red snapper was allowed.

Subsetting Trips: Species Association

A method to infer targeting for each trip was used to develop each index because no direct targeting information was available. The Stephens and MacCall (2004) multispecies approach ('SM' Method) was used to restrict the dataset to trips that likely encountered Red Snapper based on the catch species composition. The SM trip selection procedure is a widely used analytical method used in identifying a set of target trips in the absence of such information. Briefly, this approach uses the species composition of each trip in a logistic regression of species presence/absence to infer if effort on that trip occurred in similar habitat occupied by Red Snapper. If effort on a trip was determined to occur in a habitat likely occupied by Red Snapper, then that trip was used in the analysis (Stephens and MacCall 2004). This approach was applied separately for the three Stock ID regions (i.e., Eastern U.S. GOM (Stat zones 1-6), Central U.S. GOM (Stat zones 7-12) and Western U.S. GOM (Stat zones 13-21)) due to suspected differences in species compositions between regions. Substantial differences in habitat type have been noted between regions, as the Eastern U.S. GOM is dominated more by hard bottom habitats whereas the Western U.S. GOM has more artificial structure and less hard bottom. Lastly, any trips that caught exclusively Red Snapper were kept in the dataset and included in the analysis following previous decisions for other Gulf snapper analyses.

Standardization: Vertical Line Gear

A two-stage delta-lognormal generalized linear model (GLM; Lo et al. 1992) was used to standardize for variability and non-randomness in CPUE data collection methods not caused by the year effect (i.e., to factor out year to year variations in CPUE not due to changes in abundance). This method combines two separate generalized linear model (GLM) analyses of the proportion of trips that caught at least one Red Snapper (i.e., proportion of positive trips) and the catch rates of the positive trips to construct a single standardized index of abundance (Lo et al. 1992, Hinton and Maunder 2004, Maunder and Punt 2004). Parameterization of each model was accomplished using a GLM procedure, a stepwise approach and Akaike's information criteria (AIC). In the first step, the proportion positive is modeled using a logit regression assuming a binomial distribution of the response variable in a type-3 model. The response variable was the proportion of successful trips across strata. In the second step, the logarithm of CPUE on positive trips (those that caught the target species) was used as the response variable assuming a normal distribution and an identity link function in a type-3 model. The two models were then combined to provide the final standardized index of abundance. For the lognormal model, the response variable, ln(*CPUE*) for the Vertical Line fishery, was calculated as:

ln(CPUE)=ln(whole pounds of Red Snapper)/(number of lines fished x hooks per line x total hours fished))

Variable Selection

A forward stepwise regression approach was utilized within the GENMOD procedure of SAS 9.2 (SAS Institute, 2008) to quantify the relative importance of the explanatory factors. First, a GLM model was fit to the null model (only the intercept) and the AIC, deviance and degrees of freedom were calculated. Next, a suite of models was tested where each potential explanatory factor was added to the null model and the AIC, deviance, and degrees of freedom were re-calculated. The model with the factor that had the lowest AIC became the new base model and the process was repeated adding factors individually until either the AIC was no longer further reduced or all the factors were added to the model. In addition to screening using AIC, factors were also screened and not added to the model if the reduction in deviance per degree of freedom was less than one percent. This screening was implemented in order to fit a more parsimonious model, given the fact that factors which reduce the deviance by so little exert little influence on the index trend. Once a set of fixed factors was identified, first level interactions were examined with significance of these interactions evaluated between nested models using the likelihood ratio test. Significant YEAR*FACTOR interaction terms were modeled as random effects.

Development of Index

For each Vertical Line index, the results of the binomial (proportion positive) and lognormal (mean CPUE on successful trips) models were multiplied to attain a single index of abundance based on the year effect. The final delta-lognormal model was fit using the SAS macro GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute) and the SAS procedure PROC MIXED (SAS Institute Inc. 1997) following the procedures by Lo et al. (1992). To facilitate visual comparison, a relative standardized index and relative nominal CPUE series were calculated by dividing each value in the series by the mean value for each time-series.

Results and Discussion

Eastern U.S. GOM Trip Selection using Stephens and MacCall (2004)

The minimum difference between the predicted and the observed number of trips that reported Red Snapper occurred at the probability threshold of 0.45 (**Figure 2A**). The number of predicted trips were generally similar to observed trips, with both increasing until the end of the time-series (**Figure 2B**). Trips with a predicted probability greater than the critical threshold probability were considered as trips that targeted Red Snapper (**Figure 2C**). Trends in nominal CPUE were similar following application of the Stephens and MacCall (2004) approach. Nominal CPUE remained low until 1999, becoming progressively higher there after (**Figure 2D**). This method retained 14.75% of the total trips, and 53.25% of trips that reported Red Snapper. Prior to trip selection, there were 15,336 trips and the proportion positive was 0.16, and after selection there were 2,263 trips and the proportion positive was 0.57. **Table A1** provides the total trips after logbook filtering and SM trip selection per year.

The Stephens and MacCall (2004) trip subsetting approach identified 31 reef fish species which were captured with Red Snapper (**Table A2**). Scamp, Banded Rudderfish, Gray Snapper, Gag Grouper, and Red Grouper were most positively correlated to Red Snapper whereas Yellowtail Snapper, Bluestriped Grunt, Blue Runner, Hogfish, and Crevalle were most negatively correlated.

Central U.S. GOM Trip Selection using Stephens and MacCall (2004)

The minimum difference between the predicted and the observed number of trips that reported Red Snapper occurred at the probability threshold of 0.68 (**Figure 3A**). The number of predicted trips were generally similar to observed trips, with both increasing until 2003/2004 and declining thereafter (**Figure 3B**). Trips with a predicted probability greater than the critical threshold probability were considered as trips that targeted Red Snapper (**Figure 3C**). Trends in nominal CPUE were similar following application of the Stephens and MacCall (2004) approach. Nominal CPUE was highly variable prior to 2000 after which it shows a less variable but gradually declining trend until the end of the time-series (**Figure 3D**). This method retained 78% of the total trips, and 88.2% of trips that reported Red Snapper. Prior to trip selection, there were 17,516 trips and the proportion positive was 0.73, and after selection there were 13,648 trips and the proportion positive was 0.83 **Table A3** provides the total trips after logbook filtering and SM trip selection per year.

The Stephens and MacCall (2004) trip subsetting approach identified 26 reef fish species which were captured with Red Snapper (**Table A4**). Gray Triggerfish, Ocean Triggerfish, Vermilion Snapper, Lane Snapper, and Blackfin Snapper were most positively correlated to Red Snapper whereas Margate, Lg Atlantic Black Sea Bass, Yellowedge Grouper, Queen Snapper, and White Grunt were most negatively correlated.

Western U.S. GOM Trip Selection using Stephens and MacCall (2004)

The minimum difference between the predicted and the observed number of trips that reported Red Snapper occurred at the probability threshold of 0.87 (**Figure 4A**). The number of predicted trips were nearly identical to observed trips, with both increasing until the late 1990's and then remaining relatively constant through the end of the time-series (**Figure 4B**). Trips with a predicted probability greater than the critical threshold probability were considered as trips that targeted Red Snapper (**Figure 4C**). Trends in nominal CPUE were similar following application of the Stephens and MacCall (2004) approach. Nominal CPUE declined steadily until 2004 after which it increased until 2006 (**Figure 4D**). This method retained 98.1% of the total trips, and 98.8% of trips that reported Red Snapper. Prior to trip selection, there were 23,882 trips and the proportion positive was 0.96, and after selection there were 23,417 trips and the proportion positive was 0.97. **Table A5** provides the total trips after logbook filtering and SM trip selection per year.

The Stephens and MacCall (2004) trip subsetting approach identified 28 reef fish species which were captured with Red Snapper (**Table A6**). Lane Snapper, Gray Triggerfish, Red Hind, Speckled Hind, and Greater Amberjack were most positively correlated to Red Snapper whereas Queen Snapper, Silk Snapper, Creole-Fish, Blue Runner, and Blackfin Snapper were most negatively correlated.

Regional Comparison of Species Associations from Stephens and MacCall (2004)

Regional differences in species association were apparent among all three stock ID regions. (**Figure 5**). Correlations were weak among all regions with only the central and western region associations achieving a correlation greater than fifty percent (0.56). Differences in species association are likely due to difference in red snapper habitat, abundance, and fishing sector priority during the modeled timeframe.

The derived probability threshold, percent of trips retained, and proportion positive after applying the Stephens and MacCall (2004) approach varied widely across regions (**Figure 6**). For all metrics assessed, values increased as spatial area moved west (**Figure 6**).

Variable Selection

The following factors were treated as fixed effects and were examined as possible influences on the proportion of positive trips and on the catch rates of positive trips:

Eastern Gulf:

Name	DF	Details
Year	14	1993-2006
Month	11	Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
Area	2	1 (areas 1-5), 2 (area 6)
Crew	2	1 (1-2 crew), 2 (3-6 crew)
Away	4	1 (1-4 days), 2 (5-6 days), 3 (7-8 days), 4(9-11)
Hookhrs*	4	1 (0.5-96), 2 (97-216), 3 (217-434), 4 (435+)

Central Gulf:

Name	DF	Details
Year	14	1993-2006
Month	11	Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
Area	4	1 (areas 7-8), 2 (area 9), 3 (area 10), 4 (areas 11-12)
Crew	3	1 (1-2 crew), 2 (3 crew), 3 (4-6 crew)
Away	3	1 (1 day), 2 (2 days), 3 (3-11 days)
Hookhrs*	4	1 (0.5-24), 2 (25-72), 3 (73-540), 4 (541+)

Western Gulf:

Name	DF	Details
Year	14	1993-2006
Month	11	Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
Area	4	1 (areas 13-14), 2 (area 15-17), 3 (areas 18), 4 (areas 19-21)
Crew	3	1 (1-2 crew), 2 (3 crew), 3 (4-6 crew)
Away	3	1 (1 day), 2 (2 days), 3 (3-11 days)
Hookhrs*	4	1 (1-160), 2 (161-600), 3 (601-1,320), 4 (1,321+)

*Only explored as factors for modeling success because these factors were confounded with effort for the CPUE response variable in the lognormal model.

Index of Abundance

Eastern Gulf

The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive trips) components were:

$$ProportionPositive = YEAR + MONTH$$
$$ln(CPUE) = YEAR + AWAY$$

Initial model development indicated that inclusion of year*month interaction in the binomial model could improve fit; however, including the interaction term resulted in convergence issues in during final model development. Consequently, the year*month interaction term was excluded from the final model.

Diagnostics for each component of the GLM are provided in **Figure 7** and **Figure 8**. The binomial model generally overestimated the proportion of positive trips with the exception of the last few years (**Figure 7A**). The predicted proportion positive ranged from 0.48 to 0.79, and has generally remained between 0.55 and 0.73. Residual analysis of the binomial model showed no obvious patterns in the residuals by year (**Figure 7B**), or month (**Figure 7C**).

The lognormal model results suggest a good fit to the data and indicated that the assumption of a lognormal distribution for positive catch rates was appropriate for the data (**Figure 8A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals by year (**Figure 8C**), days away at sea (**Figure 8E**).

Table 1 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of trips. Nominal CPUE values fell within the 95% confidence interval of the standardized index for most years (**Figure 9**). Relative abundance has increased steadily throughout the time series, with peak abundance in 2006 and the lowest value in 1994 (**Figure 9**).

Central Gulf

The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive trips) components were:

$ProportionPositive = YEAR + MONTH$ + AREA + AWAY + HOOK + HOOK*AREA + MONTH*AREA

$$ln(CPUE) = YEAR + AWAY + AREA + AREA * AWAY + AREA * YEAR$$

Diagnostics for each component of the GLM are provided in **Figure 10** and **Figure 11**. The binomial model generally overestimated the proportion of positive trips (**Figure 10A**). The predicted proportion positive ranged from 0.61 to 0.94, and has generally remained between 0.80 and 0.90. Residual analysis of the binomial model showed no obvious patterns in the residuals (**Figures 10B – 10F**).

The lognormal model results suggest a reasonably good fit to the data and indicated that the assumption of a lognormal distribution for positive catch rates was appropriate for the data (**Figure 11A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals (**Figure 11C – 11E**).

Table 2 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of trips. Nominal CPUE values fell within the 95% confidence interval of the standardized index for all years (**Figure 12**). Relative abundance has remained relatively stable throughout the time series, with peak abundance in 2002 and the lowest value in 1997 (**Figure 12**).

Western Gulf

The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive trips) components were:

$ProportionPositive = YEAR + MONTH$ +AREA + AWAY + HOOK + HOOK*MONTH
$ln(CPUE) = YEAR + AWAY + AREA + AREA * YEAR$

Diagnostics for each component of the GLM are provided in **Figure 13** and **Figure 14**. The binomial model generally overestimated the proportion of positive trips especially in the last few years (**Figure 13A**). The predicted proportion positive ranged from 0.94 to 0.99, and has generally remained between 0.95 and 0.98. Residual analysis of the binomial model showed no obvious patterns in the residuals (**Figure 13B – 13F**).

The lognormal model results suggest a reasonably good fit to the data and indicated that the assumption of a lognormal distribution for positive catch rates was appropriate for the data (**Figure 14A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals (**Figure 14C – 14E**).

Table 3 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of trips. Nominal CPUE values fell within the 95% confidence interval of the standardized index for all years (**Figure 15**). Relative abundance has decreased steadily throughout the time series, with peak abundance in 1995 and the lowest value in 2005 (**Figure 15**).

Comments on Adequacy for Assessment

The commercial indices presented in this working paper were developed using continuity approaches applied in previous Gulf red snapper stock assessments. However, as discussed in past evaluations, concerns remain over using CFLP data to develop indices reflective of trends in relative abundance of the population. First, CFLP data reflect landings only and do not include reliable data on discarded fish. Second, the data collected on depth fished for a trip may be unreliable when reported. The logbook data forms contain a single line for entry of a single area and a single depth, which may not allow for accurate characterization of the various areas or depths fished during a single trip.

Given the abundance of Fishery independent indices that are available for red snapper, it is recommended that the commercial vertical line indices of relative abundance not be used in SEDAR 74. Consideration should be granted if specific gaps in spatial or temporal coverage are identified during the data workshop; however, the indices should still be viewed with caution due to all of the previously identified issues.

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Tables

Table 1. Numbers (N) of total and positive trips, proportion of positive trips (PPT), relative nominal CPUE, and standardized abundance index statistics for Red Snapper in the Eastern U.S. GOM for the Pre-IFQ Vertical Line index.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1993	53	35	0.66	0.252	0.300	0.191	0.470	0.229
1994	44	23	0.523	0.058	0.113	0.062	0.207	0.309
1995	72	41	0.569	0.469	0.251	0.167	0.378	0.207
1996	79	54	0.684	0.167	0.242	0.166	0.352	0.189
1997	161	77	0.478	0.168	0.382	0.269	0.543	0.177
1998	120	53	0.442	0.197	0.264	0.173	0.403	0.213
1999	147	71	0.483	0.888	1.016	0.713	1.449	0.179
2000	173	107	0.618	2.059	1.587	1.203	2.093	0.139
2001	166	92	0.554	1.148	1.102	0.792	1.535	0.167
2002	233	106	0.455	0.780	0.952	0.689	1.316	0.163
2003	251	141	0.562	0.781	1.220	0.932	1.596	0.135
2004	282	163	0.578	2.955	2.073	1.610	2.669	0.127
2005	243	146	0.601	1.811	1.857	1.432	2.408	0.131
2006	239	170	0.711	2.266	2.641	2.100	3.322	0.115

Table 2. Numbers (N) of total and positive trips, proportion of positive trips (PPT), relative nominal CPUE, and standardized abundance index statistics for Red Snapper in the Central U.S. GOM for the Pre-IFQ Vertical Line index.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1993	322	284	0.882	0.848	0.812	0.499	1.322	0.247
1994	322	303	0.941	1.399	0.979	0.608	1.575	0.241
1995	363	315	0.868	0.787	0.569	0.354	0.916	0.241
1996	335	272	0.812	0.790	0.525	0.322	0.857	0.249
1997	695	421	0.606	0.580	0.462	0.281	0.758	0.252
1998	889	668	0.751	0.739	0.852	0.533	1.362	0.238
1999	1042	801	0.769	0.891	1.112	0.698	1.772	0.236
2000	1312	1118	0.852	1.246	1.248	0.789	1.973	0.232
2001	1269	1082	0.853	1.159	1.271	0.802	2.013	0.233
2002	1461	1240	0.849	1.196	1.404	0.888	2.218	0.232
2003	1596	1337	0.838	1.035	1.244	0.787	1.966	0.232
2004	1555	1319	0.848	1.109	1.299	0.822	2.051	0.231
2005	1286	1134	0.882	1.230	1.145	0.724	1.809	0.232
2006	1201	993	0.827	0.992	1.080	0.681	1.711	0.233

Table 3. Numbers (N) of total and positive trips, proportion of positive trips (PPT), relative nominal CPUE, and standardized abundance index statistics for Red Snapper in the Western U.S. GOM for the Pre-IFQ Vertical Line index.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1993	901	866	0.961	1.644	1.384	1.033	1.854	0.147
1994	552	544	0.986	1.426	1.270	0.946	1.704	0.148
1995	1281	1272	0.993	1.652	1.452	1.094	1.928	0.142
1996	1233	1219	0.989	1.347	1.317	0.992	1.750	0.143
1997	2226	2168	0.974	1.082	1.126	0.842	1.507	0.146
1998	2372	2306	0.972	0.987	0.995	0.748	1.324	0.144
1999	1985	1921	0.968	0.784	0.931	0.699	1.239	0.144
2000	1938	1890	0.975	0.810	0.928	0.698	1.233	0.143
2001	1931	1834	0.950	0.764	0.877	0.659	1.166	0.144
2002	1821	1768	0.971	0.773	0.773	0.582	1.025	0.142
2003	1805	1722	0.954	0.709	0.802	0.605	1.065	0.142
2004	1997	1881	0.942	0.612	0.675	0.509	0.895	0.142
2005	1617	1541	0.953	0.637	0.658	0.495	0.874	0.143
2006	1758	1691	0.962	0.773	0.812	0.612	1.079	0.142

Figures

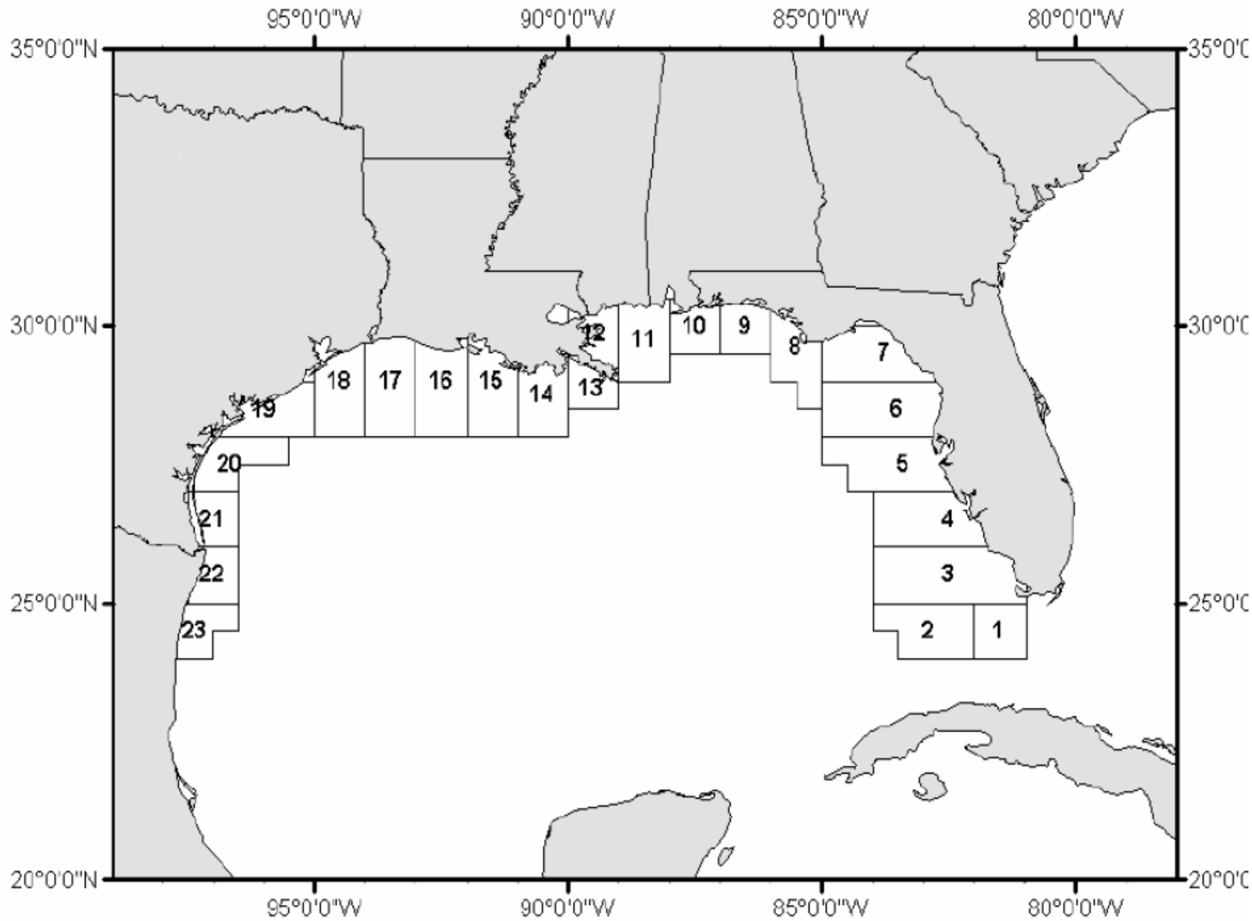

Figure 1. National Marine Fisheries Service statistical shrimp reporting grids.

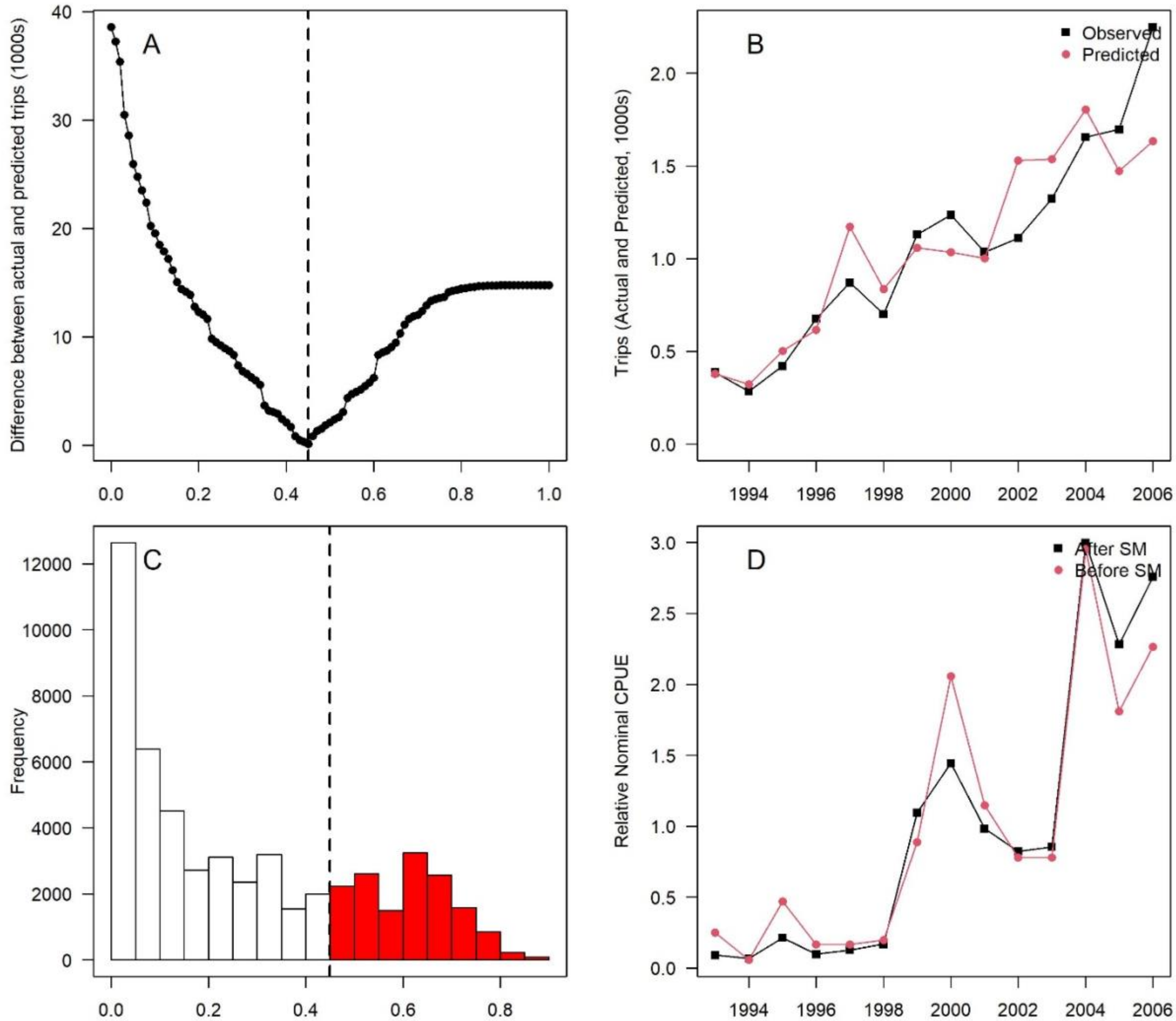

Figure 2. Stephens and MacCall (2004) trip selection diagnostics for the Pre-IFQ Vertical Line for the Eastern U.S. GOM. (A) The difference between the number of records in which Red Snapper are observed and the number in which they are predicted to occur for each probability threshold; (B) The number of actual and predicted trips; (C) Histogram of probabilities generated by the species-based regression (trips that targeted Red Snapper given in red); and (D) Nominal CPUE before ("Before SM") and after ("After SM") Stephens and MacCall (2004) trip selection. The dashed vertical line indicates the critical value where false prediction is minimized.

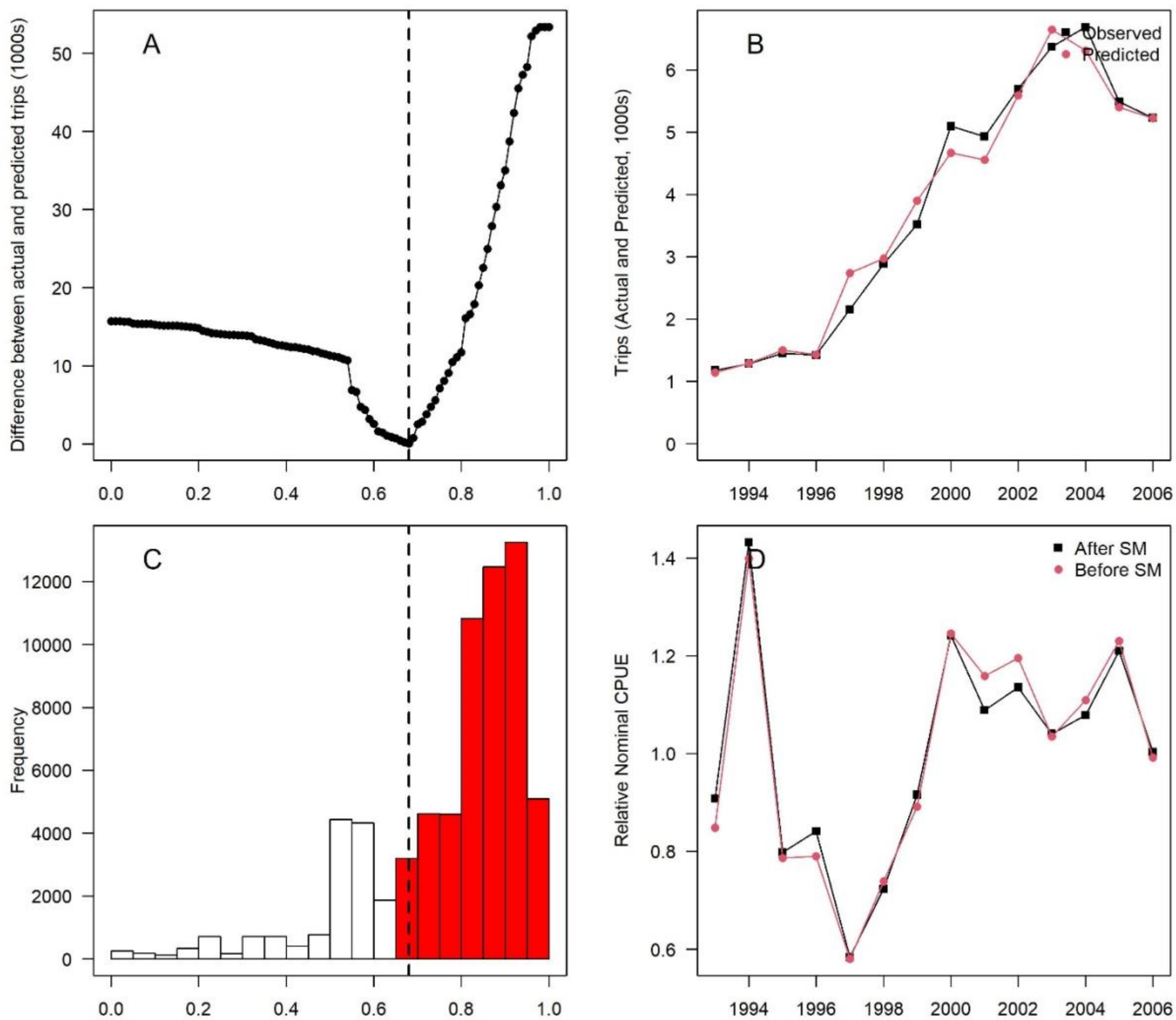

Figure 3. Stephens and MacCall (2004) trip selection diagnostics for the Pre-IFQ Vertical Line for the Central U.S. GOM. (A) The difference between the number of records in which Red Snapper are observed and the number in which they are predicted to occur for each probability threshold; (B) The number of actual and predicted trips; (C) Histogram of probabilities generated by the species-based regression (trips that targeted Red Snapper given in red); and (D) Nominal CPUE before ("Before SM") and after ("After SM") Stephens and MacCall (2004) trip selection. The dashed vertical line indicates the critical value where false prediction is minimized.

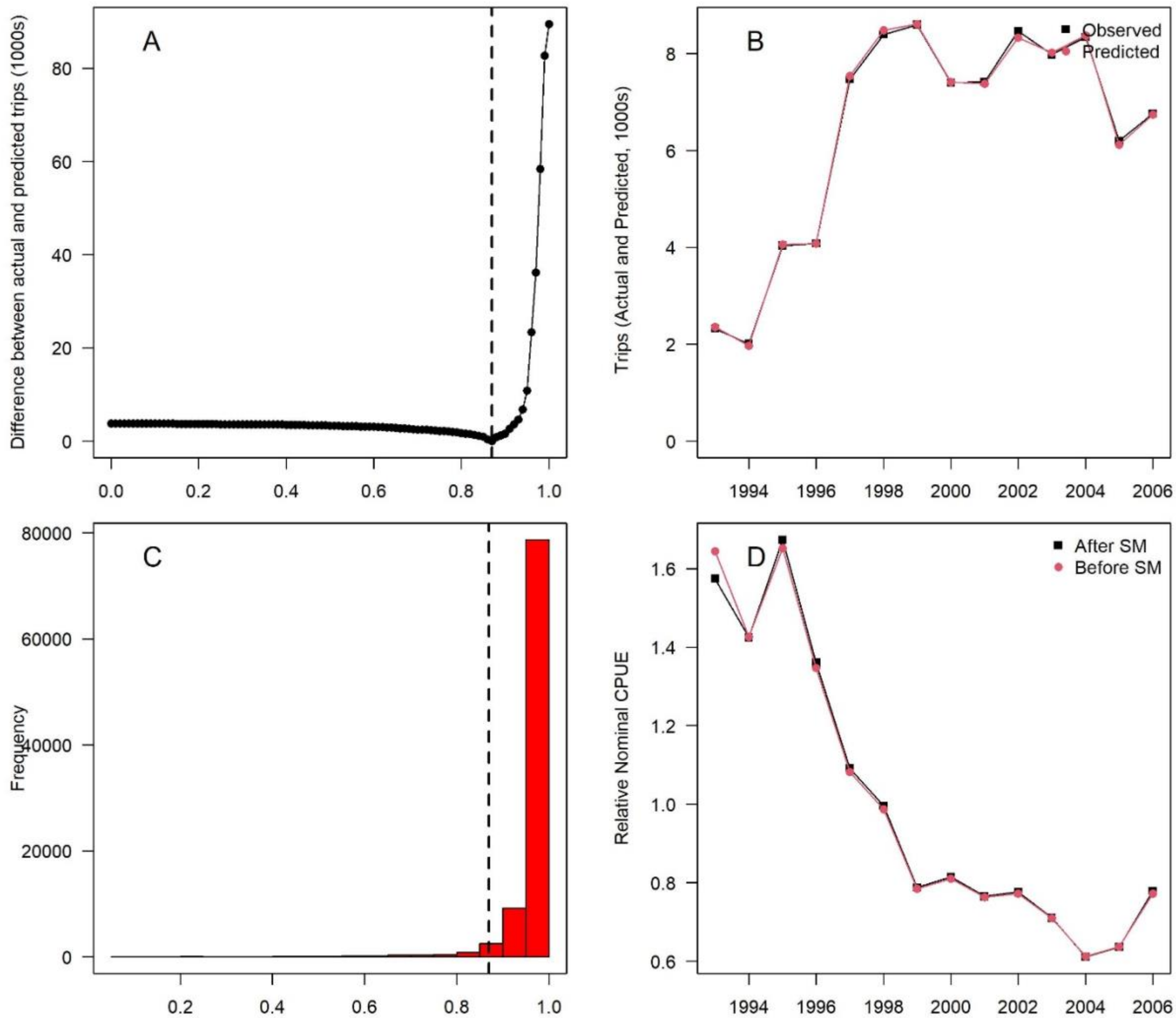

Figure 4. Stephens and MacCall (2004) trip selection diagnostics for the Pre-IFQ Vertical Line for the Western U.S. GOM. (A) The difference between the number of records in which Red Snapper are observed and the number in which they are predicted to occur for each probability threshold; (B) The number of actual and predicted trips; (C) Histogram of probabilities generated by the species-based regression (trips that targeted Red Snapper given in red); and (D) Nominal CPUE before ("Before SM") and after ("After SM") Stephens and MacCall (2004) trip selection. The dashed vertical line indicates the critical value where false prediction is minimized.

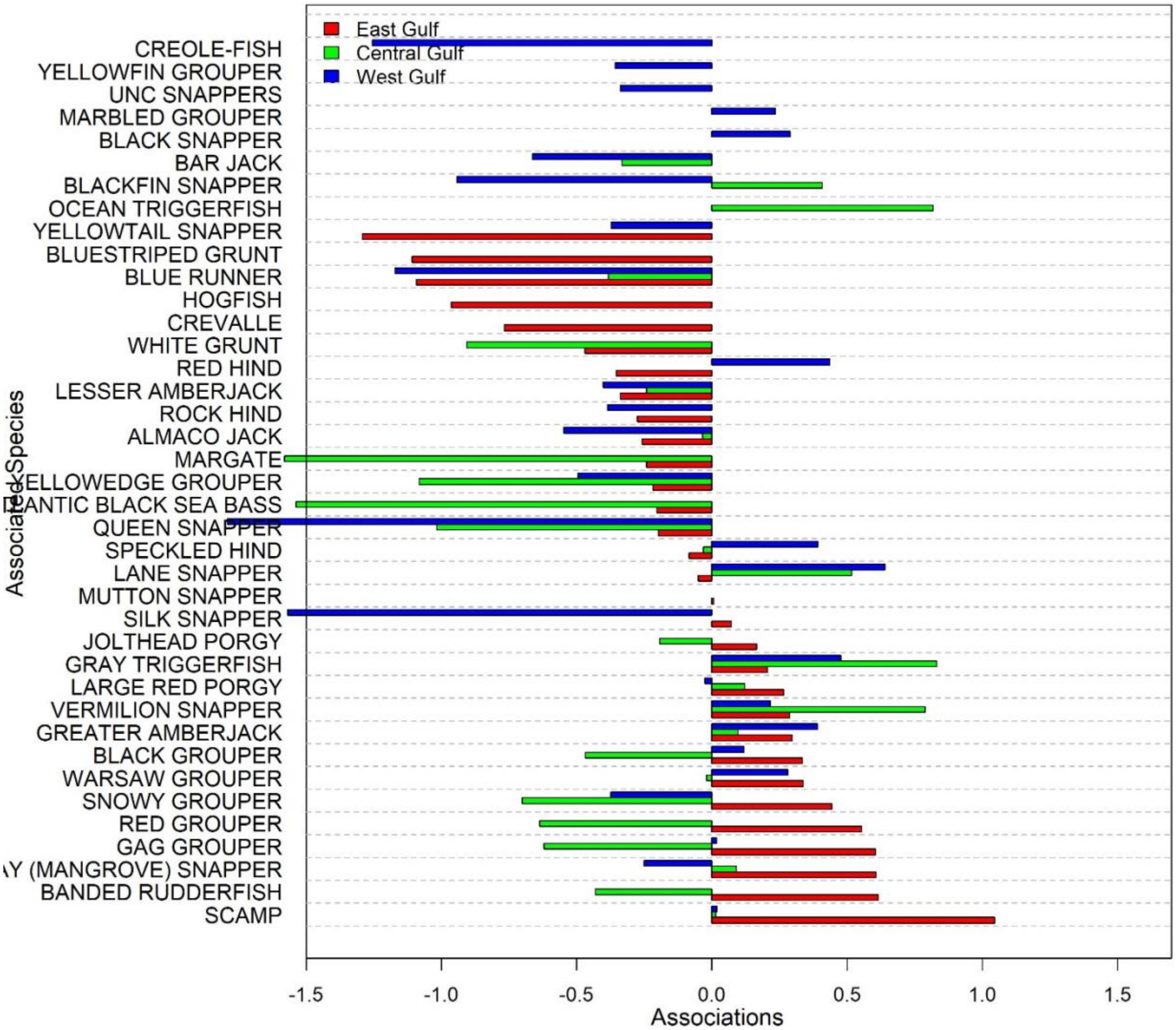

Figure 5. Association coefficients of other species with Red Snapper across regions in the U.S. GOM for the Pre-IFQ Vertical Line fishery. Positive numbers indicate a positive correlation.

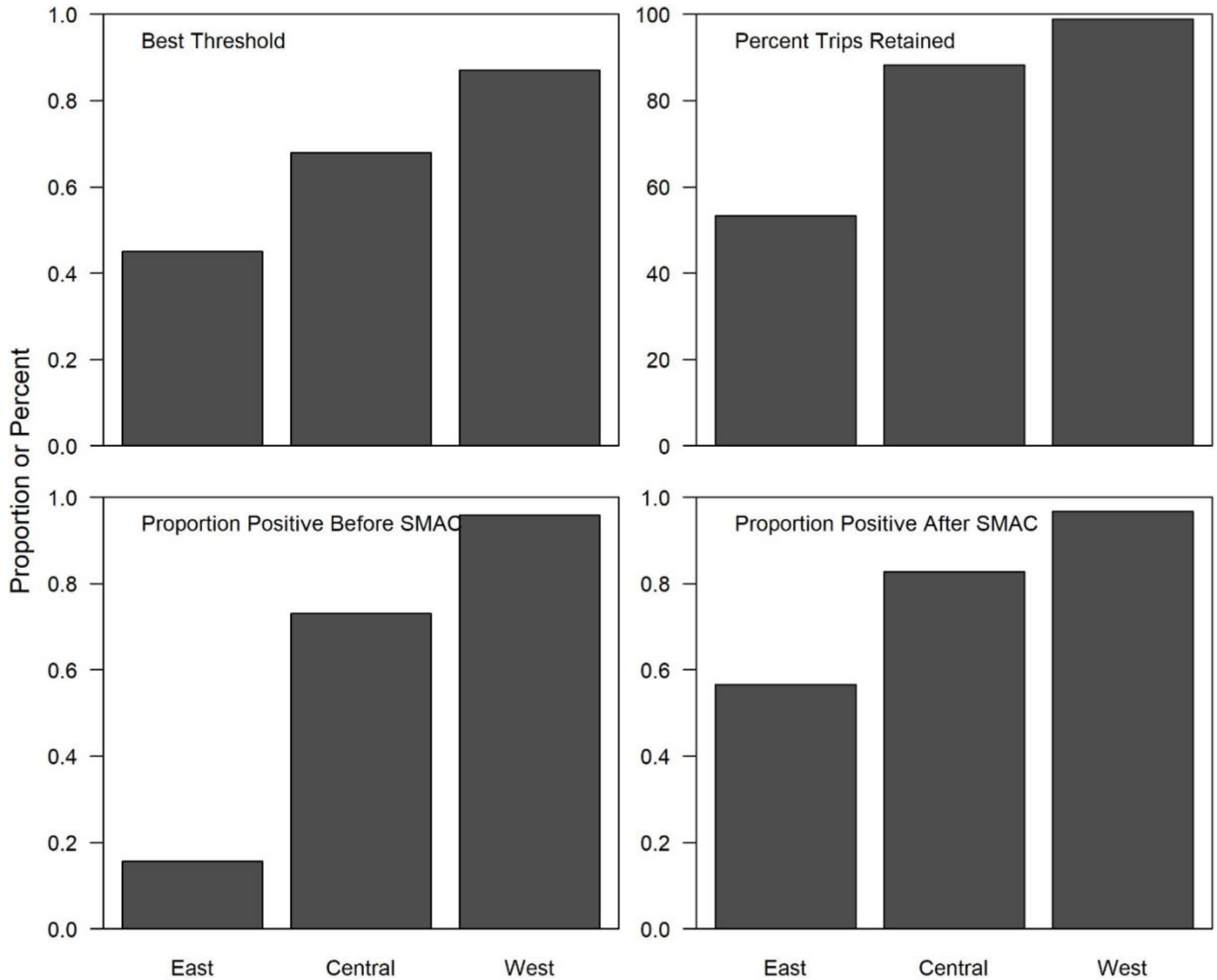

Figure 6. Stephens and MacCall (2004) statistics across regions for associations with Red Snapper for the Pre-IFQ Vertical Line fishery.

Figure 7. Diagnostic plots for the binomial model for Red Snapper in the Eastern U.S. GOM for the Pre-IFQ Vertical Line fishery. Shown here are the predicted (solid line) and observed proportion of positive trips by year (A) and the residuals from the binomial model by year (B), and month (E).

Figure 8. Diagnostic plots for the lognormal model of catch rates on positive trips for Red Snapper in the Eastern U.S. GOM for the Pre-IFQ Vertical Line fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C), and days away at sea (E). The red lines represent the expected normal distribution.

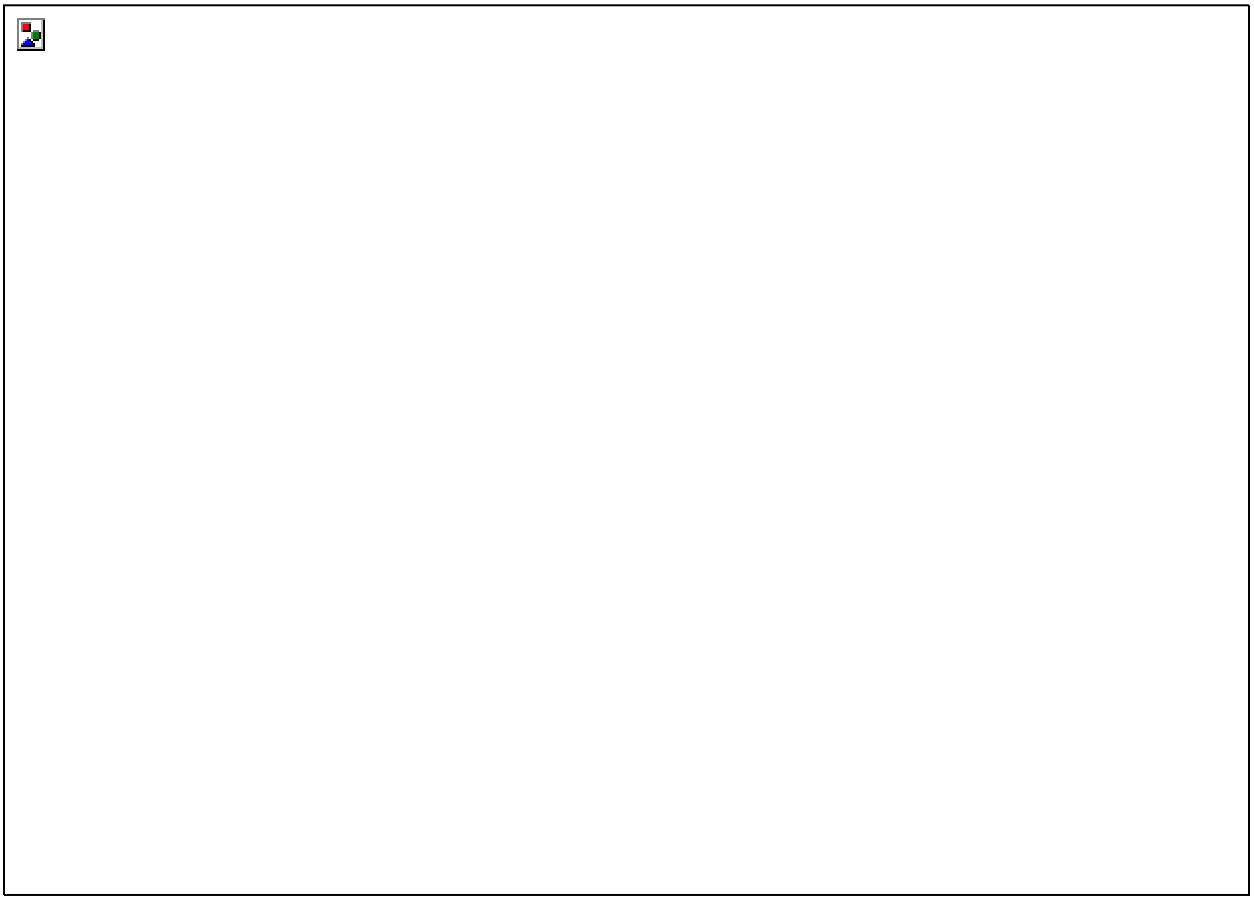

Figure 9. Standardized index with 95% confidence interval, and nominal CPUE for Red Snapper in the Eastern U.S. GOM for the Pre-IFQ Vertical Line fishery. The index was scaled to the mean value of the entire time series.

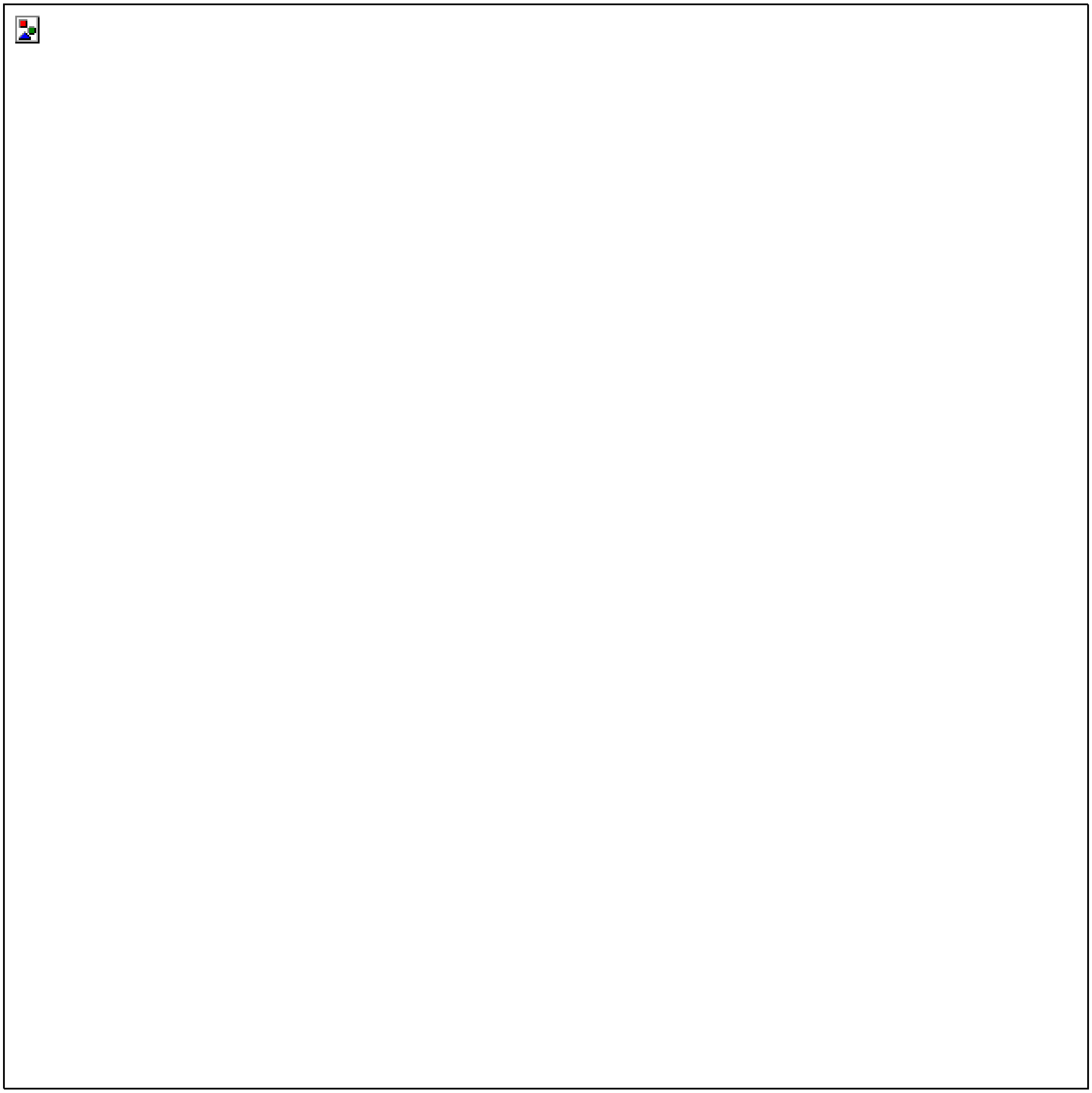

Figure 10. Diagnostic plots for the binomial model for Red Snapper in the Central U.S. GOM for the Pre-IFQ Vertical Line fishery. Shown here are the predicted (solid line) and observed proportion of positive trips by year (A) and the residuals from the binomial model by year (B), area (C), days away at sea (D), month (E), and hook hours (F).

Figure 11. Diagnostic plots for the lognormal model of catch rates on positive trips for Red Snapper in the Central U.S. GOM for the Pre-IFQ Vertical Line fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C), area (D), and days away at sea (E). The red lines represent the expected normal distribution.

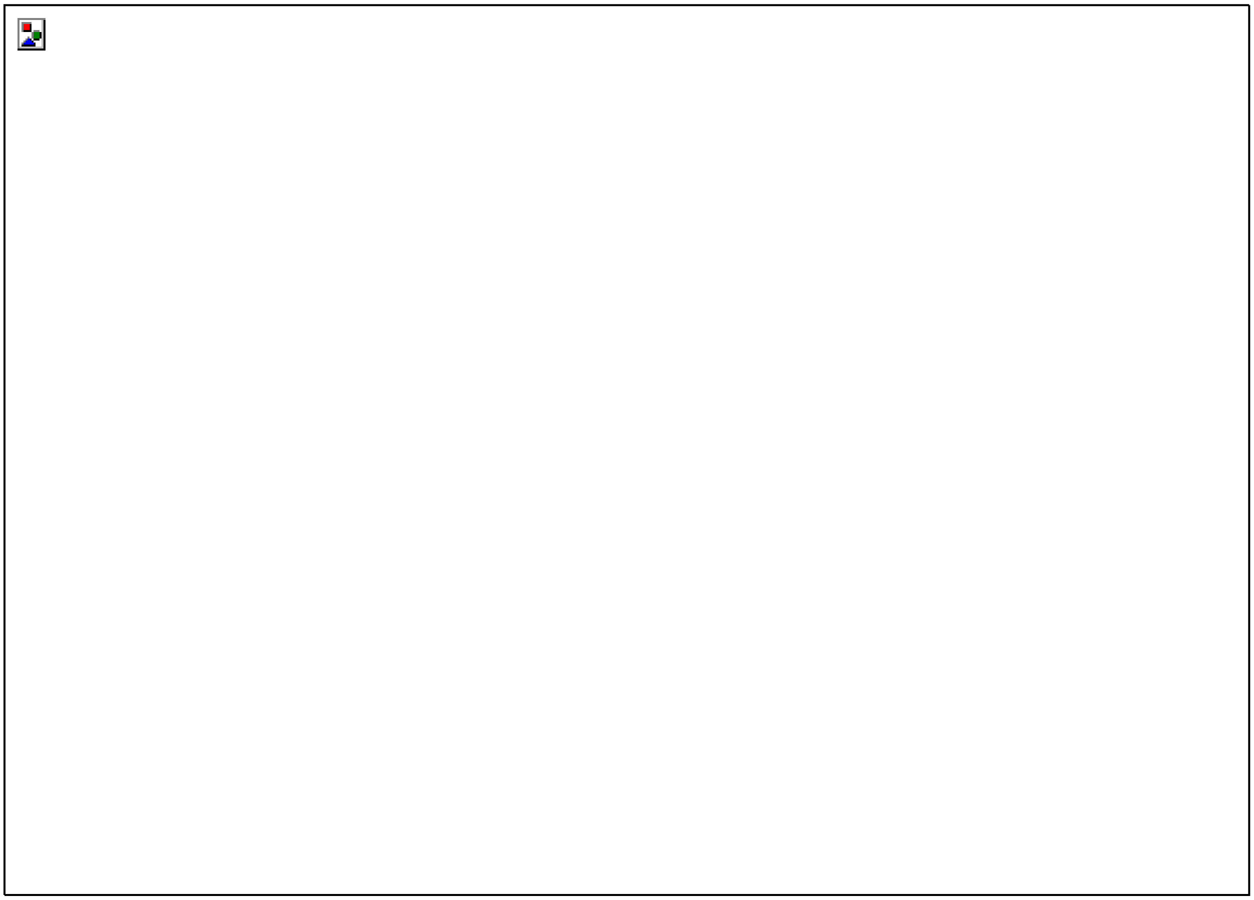

Figure 12. Standardized index with 95% confidence interval, and nominal CPUE for Red Snapper in the Central U.S. GOM for the Pre-IFQ Vertical Line fishery. The index was scaled to the mean value of the entire time series.

Figure 13. Diagnostic plots for the binomial model for Red Snapper in the Western U.S. GOM for the Pre-IFQ Vertical Line fishery. Shown here are the predicted (solid line) and observed proportion of positive trips by year (A) and the residuals from the binomial model by year (B), area (C), away days at sea (D), month (E), and hook hours (F).

Figure 14. Diagnostic plots for the lognormal model of catch rates on positive trips for Red Snapper in the Western U.S. GOM for the Pre-IFQ Vertical Line fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C), area (D), and days away at sea (E). The red lines represent the expected normal distribution.

Figure 15. Standardized index with 95% confidence interval, and nominal CPUE for Red Snapper in the Western U.S. GOM for the Pre-IFQ Vertical Line fishery. The index was scaled to the mean value of the entire time series.

Appendix A

Table A1. Total trips, positive trips (Pos), and proportion of positive trips (PPos) before (Total) and after trip selection (Stephens and MacCall, SMAC) for Red Snapper in the Pre-IFQ Vertical Line for the Eastern U.S. GOM. The proportion of trips retained is also provided.

Year	Trips Total	Pos Total	PPos Total	Trips SMAC	Pos SMAC	PPos SMAC	Trips Retained
1993	985	56	0.0569	53	35	0.660	0.054
1994	905	42	0.0464	44	23	0.523	0.049
1995	863	61	0.0707	72	41	0.569	0.083
1996	655	96	0.1466	79	54	0.684	0.121
1997	1263	118	0.0934	161	77	0.478	0.127
1998	849	97	0.1143	120	53	0.442	0.141
1999	1210	175	0.1446	147	71	0.483	0.121
2000	1163	221	0.1900	173	107	0.618	0.149
2001	1039	177	0.1704	166	92	0.554	0.160
2002	1322	185	0.1399	233	106	0.455	0.176
2003	1265	221	0.1747	251	141	0.562	0.198
2004	1336	274	0.2051	282	163	0.578	0.211
2005	1299	310	0.2386	243	146	0.601	0.187
2006	1182	369	0.3122	239	170	0.711	0.202

Table A2. Association coefficients of other species with Red Snapper in at least 1% of Vertical Line trips in the Eastern U.S. GOM for the Pre-IFQ Vertical Line fishery. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
1.045	SCAMP	*Mycteroperca phenax*
0.615	BANDED RUDDERFISH	*Seriola zonata*
0.606	GRAY (MANGROVE) SNAPPER	*Lutjanus griseus*
0.605	GAG GROUPER	*Mycteroperca microlepis*
0.553	RED GROUPER	*Epinephelus morio*
0.443	SNOWY GROUPER	*Epinephelus niveatus*
0.337	WARSAW GROUPER	*Epinephelus nigritus*
0.334	BLACK GROUPER	*Mycteroperca bonaci*
0.296	GREATER AMBERJACK	*Seriola dumerili*
0.287	VERMILION SNAPPER	*Rhomboplites aurorubens*
0.266	LARGE RED PORGY	*Pagrus pagrus*
0.205	GRAY TRIGGERFISH	*Balistes capriscus*
0.166	JOLTHEAD PORGY	*Calamus bajonado*
0.072	SILK SNAPPER	*Lutjanus vivanus*
0.007	MUTTON SNAPPER	*Lutjanus analis*
-0.051	LANE SNAPPER	*Lutjanus synagris*
-0.084	SPECKLED HIND	*Epinephelus drummondhayi*
-0.198	QUEEN SNAPPER	*Etelis oculatus*
-0.204	LG ATLANTIC BLACK SEA BASS	*Centropristis striata*
-0.218	YELLOWEDGE GROUPER	*Epinephelus flavolimbatus*
-0.242	MARGATE	*Haemulon album*
-0.258	ALMACO JACK	*Seriola rivoliana*
-0.275	ROCK HIND	*Epinephelus adscensionis*
-0.339	LESSER AMBERJACK	*Seriola fasciata*
-0.353	RED HIND	*Epinephelus guttatus*
-0.470	WHITE GRUNT	*Haemulon plumieri*
-0.768	CREVALLE	*Caranx hippos*
-0.963	HOGFISH	*Lachnolaimus maximus*
-1.092	BLUE RUNNER	*Caranx crysos*
-1.109	BLUESTRIPED GRUNT	*Haemulon sciurus*
-1.292	YELLOWTAIL SNAPPER	*Ocyurus chrysurus*

Table A3. Total trips, positive trips (Pos), and proportion of positive trips (PPos) before (Total) and after trip selection (Stephens and MacCall, SMAC) for Red Snapper in the Pre-IFQ Vertical Line for the Central U.S. GOM. The proportion of trips retained is also provided.

Year	Trips Total	Pos Total	PPos Total	Trips SMAC	Pos SMAC	PPos SMAC	Trips Retained
1993	359	305	0.8496	322	284	0.882	0.897
1994	374	317	0.8476	322	303	0.941	0.861
1995	428	330	0.7710	363	315	0.868	0.848
1996	378	293	0.7751	335	272	0.812	0.886
1997	854	482	0.5644	695	421	0.606	0.814
1998	1145	749	0.6541	889	668	0.751	0.776
1999	1264	867	0.6859	1042	801	0.769	0.824
2000	1703	1312	0.7704	1312	1118	0.852	0.770
2001	1718	1262	0.7346	1269	1082	0.853	0.739
2002	1969	1415	0.7186	1461	1241	0.849	0.742
2003	2011	1474	0.7330	1596	1337	0.838	0.794
2004	2094	1556	0.7431	1555	1319	0.848	0.743
2005	1643	1270	0.7730	1286	1134	0.882	0.783
2006	1576	1169	0.7418	1201	993	0.827	0.762

Table A4. Association coefficients of other species with Red Snapper in at least 1% of Vertical Line trips in the Central U.S. GOM for the Pre-IFQ Vertical Line fishery. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
0.831	GRAY TRIGGERFISH	*Balistes capriscus*
0.817	OCEAN TRIGGERFISH	*Canthidermis sufflamen*
0.788	VERMILION SNAPPER	*Rhomboplites aurorubens*
0.516	LANE SNAPPER	*Lutjanus synagris*
0.408	BLACKFIN SNAPPER	*Lutjanus buccanella*
0.122	LARGE RED PORGY	*Pagrus pagrus*
0.096	GREATER AMBERJACK	*Seriola dumerili*
0.091	GRAY (MANGROVE) SNAPPER	*Lutjanus griseus*
0.014	SCAMP	*Mycteroperca phenax*
-0.020	WARSAW GROUPER	*Epinephelus nigritus*
-0.031	SPECKLED HIND	*Epinephelus drummondhayi*
-0.034	ALMACO JACK	*Seriola rivoliana*
-0.193	JOLTHEAD PORGY	*Calamus bajonado*
-0.241	LESSER AMBERJACK	*Seriola fasciata*
-0.333	BAR JACK	*Caranx ruber*
-0.382	BLUE RUNNER	*Caranx crysos*
-0.431	BANDED RUDDERFISH	*Seriola zonata*
-0.468	BLACK GROUPER	*Mycteroperca bonaci*
-0.621	GAG GROUPER	*Mycteroperca microlepis*
-0.637	RED GROUPER	*Epinephelus morio*
-0.702	SNOWY GROUPER	*Epinephelus niveatus*
-0.905	WHITE GRUNT	*Haemulon plumieri*
-1.018	QUEEN SNAPPER	*Etelis oculatus*
-1.082	YELLOWEDGE GROUPER	*Epinephelus flavolimbatus*
-1.537	LG ATLANTIC BLACK SEA BASS	*Centropristis striata*
-1.580	MARGATE	*Haemulon album*

Table A5. Total trips, positive trips (Pos), and proportion of positive trips (PPos) before (Total) and after trip selection (Stephens and MacCall, SMAC) for Red Snapper in the Pre-IFQ Vertical Line for the Western U.S. GOM. The proportion of trips retained is also provided.

Year	Trips Total	Pos Total	PPos Total	Trips SMAC	Pos SMAC	PPos SMAC	Trips Retained
1993	959	869	0.906	901	866	0.961	0.940
1994	564	551	0.977	552	544	0.986	0.979
1995	1289	1273	0.988	1281	1272	0.993	0.994
1996	1246	1226	0.984	1233	1219	0.989	0.990
1997	2256	2186	0.969	2226	2169	0.974	0.987
1998	2399	2321	0.967	2372	2306	0.972	0.989
1999	2021	1941	0.960	1985	1921	0.968	0.982
2000	1973	1913	0.970	1938	1889	0.975	0.982
2001	1982	1874	0.946	1931	1834	0.950	0.974
2002	1863	1804	0.968	1821	1768	0.971	0.977
2003	1841	1744	0.947	1805	1722	0.954	0.980
2004	2050	1915	0.934	1997	1882	0.942	0.974
2005	1656	1565	0.945	1617	1541	0.953	0.976
2006	1783	1714	0.961	1758	1692	0.962	0.986

Table A6. Association coefficients of other species with Red Snapper in at least 1% of Vertical Line trips in the Western U.S. GOM for the Pre-IFQ Vertical Line fishery. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
0.640	LANE SNAPPER	*Lutjanus_synagris*
0.477	GRAY TRIGGERFISH	*Balistes_capriscus*
0.435	RED HIND	*Epinephelus_guttatus*
0.392	SPECKLED HIND	*Epinephelus_drummondhayi*
0.390	GREATER AMBERJACK	*Seriola_dumerili*
0.289	BLACK SNAPPER	*Apsilus_dentatus*
0.280	WARSAW GROUPER	*Epinephelus_nigritus*
0.234	MARBLED GROUPER	*Epinephelus_inermis*
0.216	VERMILION SNAPPER	*Rhomboplites_aurorubens*
0.118	BLACK GROUPER	*Mycteroperca_bonaci*
0.019	SCAMP	*Mycteroperca_phenax*
0.017	GAG GROUPER	*Mycteroperca_microlepis*
-0.025	LARGE RED PORGY	*Pagrus_pagrus*
-0.250	GRAY (MANGROVE) SNAPPER	*Lutjanus_griseus*
-0.339	UNC SNAPPERS	*Lutjanidae*
-0.358	YELLOWFIN GROUPER	*Mycteroperca_venenosa*
-0.373	YELLOWTAIL SNAPPER	*Ocyurus_chrysurus*
-0.374	SNOWY GROUPER	*Epinephelus_niveatus*
-0.386	ROCK HIND	*Epinephelus_adscensionis*
-0.402	LESSER AMBERJACK	*Seriola_fasciata*
-0.494	YELLOWEDGE GROUPER	*Epinephelus_flavolimbatus*
-0.547	ALMACO JACK	*Seriola_rivoliana*
-0.663	BAR JACK	*Caranx_ruber*
-0.942	BLACKFIN SNAPPER	*Lutjanus_buccanella*
-1.172	BLUE RUNNER	*Caranx_crysos*
-1.256	CREOLE-FISH	*Paranthias_furcifer*
-1.569	SILK SNAPPER	*Lutjanus_vivanus*
-1.791	QUEEN SNAPPER	*Etelis_oculatus*