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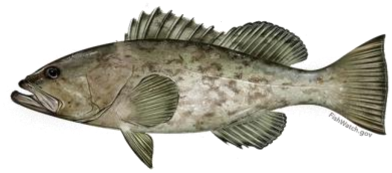

Standardized Catch Rate Indices for Gag Grouper (*Mycteroperca microlepis*) during 1986-2019 by the U.S. Gulf of Mexico Charterboat and Private Boat Recreational Fishery

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Keywords

Catch, fishing effort, CPUE, recreational fisheries, private and charterboat, Gag and Black Grouper

Abstract

A delta-lognormal index of abundance for the Gulf of Mexico private and charterboat recreational fishery was constructed for the SEDAR72 Operational Gag Grouper stock assessment using data from the Marine Recreational Information Program. Two mode specific indices and a combined mode index were developed using species associations to subset the data and standardized with a two-stage delta-lognormal generalized linear model. The resulting standardized indices reveal similar index trends when compared to the SEDAR33 index. The SEDAR72 combined mode standardized index indicates catch rates were relatively high from 1995-2000, remained relatively low between 2000 and 2005, and have been decreasing since 2010 with a slight increase in 2017 and 2018.

Introduction

The recreational fishery in the Gulf of Mexico is surveyed by the Marine Recreational Information Program (MRIP) conducted by NOAA Fisheries (formerly the Marine Recreational Fisheries Statistics Survey, MRFSS), the Texas Marine Sport-Harvest Monitoring Program conducted by the Texas Parks and Wildlife Department (TPWD), and the Southeast Region Headboat Survey (SRHS) conducted by NOAA Fisheries. MRIP/MRFSS has monitored shore based, charterboat and private/rental boat angler fishing in the Gulf of Mexico since 1981. MRIP data were used to construct indices of Gag Grouper catch rates in the Gulf of Mexico following the same procedures used in SEDAR33. However, for SEDAR72 interviews were selected using the Stephens and MacCall (2004) method as opposed to the guild approach utilized in SEDAR33 and a combined index was developed in addition to the two mode-specific indices. The indices were constructed using a delta-lognormal generalized linear model.

Materials and Methods

MRIP Data

MRIP collects information on participation, effort, and species-specific catch. Data are collected to provide catch and effort estimates in two-month periods ("waves") for each recreational fishing mode (shore fishing, private/rental boat, charterboat, or headboat/charterboat combined prior to 1986) and for each area of fishing (inshore, state Territorial Seas, U.S. Exclusive Economic Zone), in each Gulf of Mexico state (except Texas). Total catch information is collected by MRIP on fish landed whole and observed by interviewers ("Type A"), fish reported as killed by the fishers ("Type B1") and fish reported as released alive by the fishers ("Type B2").

Data from the MRIP dockside interviews were used to characterize abundance trends of Gag Grouper in the Gulf of Mexico. Information on effort included hours fished and number of anglers as reported to the interviewer. Catch that was not observed by the interviewer (B1 and B2) was adjusted upwards by the ratio of non-interviewed to interviewed anglers in each group of anglers. The catch per unit effort was calculated on an individual group basis (i.e., by leader) and was equal to the number of fish caught (A + B1 + B2) divided by the effort, where effort was the product of the number of anglers and the total hours fished. Due to species identification concerns, all reported fish identified as Black Grouper were considered and retained as Gag grouper.

MRIP Data Filtering

Data were filtered following the same steps as SEDAR33:
1. Data in the Gulf of Mexico were limited to interviews that took place in Florida (excluding Monroe County).
2. Only interviews associated with private and charterboat fishing modes fishing hook and line gear were retained.
3. Interviews that reported shore-based fishing or fishing in inshore waters were excluded.
4. Interviews with possible error in effort information or in catch amount were excluded.
5. Data prior to 1986 were excluded.

Subsetting Interviews: Species Association

The Stephens and MacCall (2004) approach was used to restrict the dataset to anglers that likely encountered Gag Grouper based on the catch species composition. This approach was applied separately for the Charterboat, Private, and Charterboat and Private combined due to potential differences in species compositions between fishing modes.

Standardization

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 leaders that caught at least one Gag Grouper (i.e., proportion of positive interviews) and the catch rates of the positive leaders to construct a single standardized index of abundance. In the first step, the proportion positive is modeled using a logit regression assuming a binomial distribution of the response variable. In the second step, the logarithm of CPUE on positive interviews (those that caught the target species) was used as the response variable assuming a normal distribution and an identity link function. The two models were then combined to provide the final standardized index of abundance. Parameterization of each model was accomplished using a GLM procedure. For the lognormal models, the response variable, ln(*CPUE*), was calculated:

$$ln(CPUE) = ln(A + B1 + B2) / (anglers \ x \ hours \ fished)$$

A forward stepwise regression approach was utilized within the GENMOD procedure of SAS 9.2 (SAS Institute, 2008). In this procedure, factors were added to the base model one at a time based on the percent reduction in deviance per degree of freedom. With each run of the model, the factor that caused the highest reduction in deviance was added to the base model (assuming the factor was significant based on a Chi-Square test with probability ≤ 0.05) until no factor reduced the percent deviance by the pre-specified level of 1%. Once a set of fixed factors was identified, first level interactions were examined. The significance of these interactions was evaluated between nested models using the likelihood ratio test. Interactions were screened and were only retained if the model improvement was significant according to the likelihood ratio test ($p < 0.0001$). Significant interaction terms were modeled as random effects.

Results of the binomial (proportion positive) and lognormal (mean CPUE on successful trips) models were then 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).

Results and Discussion

Species Associations - Stephens and MacCall (2004) Approach - Charterboat

The minimum difference between the predicted and the observed number of interviews that reported Gag Grouper occurred at the probability threshold of 0.41 (**Figure 1A**). Predicted interviews showed a general increasing trend until the 2000s then declined, and were overestimated at the end of the timeseries (**Figure 1B**). Interviews with a predicted probability greater than the critical threshold probability were considered as interviews that targeted Gag Grouper (**Figure 1C**). Nominal CPUE was relatively similar before and after applying the Stephens and MacCall (2004) approach, with the exception of the late-1980s and 1995 (**Figure 1D**). This method retained 32.6% of the total interviews, and 63.8% of interviews that reported

Gag. Prior to trip selection, there were 27,131 interviews and the proportion positive was 0.33, and after selection there were 8,858 interviews and the proportion positive was 0.65.

The Stephens and MacCall (2004) trip subsetting approach identified 48 species which were captured with Gag Grouper and reflected either positive or negative associations (**Table 1**). For example, Red Grouper, Red Snapper, White Grunt, Scamp, and Black Sea Bass are positively correlated to Gag Grouper while Spotted Seatrout, Remora Family, Tomtate, Bank Sea Bass, and Herring Family are negatively correlated.

Species Associations - Stephens and MacCall (2004) Approach - Private

The minimum difference between the predicted and the observed number of interviews that reported Gag Grouper occurred at the probability threshold of 0.26 (**Figure 2A**). Predicted interviews showed a general increasing trend until the 2000s then declined, and were overestimated at the beginning and end of the time series (**Figure 2B**). Interviews with a predicted probability greater than the critical threshold probability were considered as interviews that targeted Gag Grouper (**Figure 2C**). Nominal CPUE was relatively similar before and after applying the Stephens and MacCall (2004) approach, with the exception of the mid-1980s and the mid-2000s (**Figure 2D**). This method retained 10.7% of the total interviews, and 55.4% of interviews that reported Gag Grouper. Prior to trip selection, there were 119,035 interviews and the proportion positive was 0.1, and after selection there were 12,759 interviews and the proportion positive was 0.49.

The Stephens and MacCall (2004) trip subsetting approach identified 38 species which were captured with Gag Grouper and reflected either positive or negative associations (**Table 2**). For example, Red Grouper, White Grunt, Cobia, Gray Snapper, and Red Snapper are positively correlated to Gag Grouper while Red Drum, Spotted Seatrout, Gafftopsail Catfish, Hardhead Catfish, and Common Snook are negatively correlated.

Species Associations - Stephens and MacCall (2004) Approach - Charterboat and Private combined

The minimum difference between the predicted and the observed number of interviews that reported Gag Grouper occurred at the probability threshold of 0.33 (**Figure 3A**). Predicted interviews showed a general increasing trend until the 2000s then declined, and were overestimated at the beginning and end of the time series (**Figure 3B**). Interviews with a predicted probability greater than the critical threshold probability were considered as interviews that targeted Gag Grouper (**Figure 3C**). Nominal CPUE was relatively similar before and after applying the Stephens and MacCall (2004) approach, with the exception of the early 1990's and the early 2000s (**Figure 3D**). This method retained 14.5% of the total interviews, and 59.1% of interviews that reported Gag Grouper. Prior to trip selection, there were 146,166 interviews and the proportion positive was 0.14, and after selection there were 21,235 interviews and the proportion positive was 0.57.

The Stephens and MacCall (2004) trip subsetting approach identified 46 species which were captured with Gag Grouper and reflected either positive or negative associations (**Table 3**). For example, Red Grouper, Red Snapper, Scamp, White Grunt, and Gray Snapper are positively correlated to Gag Grouper while Spotted Seatrout, Gafftopsail Catfish, Red Drum, Hardhead Catfish, and Sand Perch are negatively correlated.

Trends in Species Associations Between Fishing Modes for the Stephens and MacCall (2004) approach

Trends in species associations across modes was similar with the exception of several species in the Charterboat mode, which were not observed in the private, or the combined modes (**Figure 4**).

The derived probability threshold and proportion positive before applying the Stephens and MacCall (2004) were highest for Charterboat (**Figure 5**). This was also observed after Stephens and MacCall was applied; the percent of interviews retained and the proportion positive were higher in the Charterboat mode compared to the Private and Combined modes (**Figure 5**).

Variable Selection Charterboat, Private and Combined Modes

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

Name	Levels	Details
Year	34	1986-2019
Season	6	Dec-Jan, Feb-Mar, Apr-May, Jun-Jul, Aug-Sep, Oct-Nov
Hrsf*	5	2, 4, 6, 8, 9+
Area	2	State and EEZ

*Hours fished (Hrsf) was only explored as factor for modeling success.

Annual Abundance Indices for Charterboat

Final deviance tables are included in **Table 4**. The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive interviews) components were:

$$ProportionPositive = YEAR + SEASON + HRSF + YEAR * SEASON$$

$$ln(CPUE) = YEAR + SEASON + YEAR * SEASON$$

For the binomial model, year, season, hours fished were significant variables, as was the interaction term year and season (**Table 4**).

Diagnostics for each component of the GLM are provided in **Figure 6** and **Figure 7**. The binomial model consistently estimated the proportion of positive interviews (**Figure 6A**). The proportion positive ranged from 0.22 to 0.87, and has generally remained between 0.44 and 0.78. Residual analysis of the binomial model showed no obvious patterns in the residuals by year (**Figure 6B**), season (**Figure 6C**), or hours fished (**Figure 6D**).

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 7A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals by year (**Figure 7C**) or season (**Figure 7D**).

Table 5 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of interviews. Nominal CPUE values fell within the 95% confidence interval of the standardized index, with the exception of the values in years 1990 and 1996 (**Figure 8**). Relative abundance generally remained below the time series mean in the 1980s and early 1990s and increased to above the time series mean in the mid-1990s until 2005. The index showed a continuous decline from 2011 to the end of the time series. Relative abundance peaked in 1995, and was at the lowest value in 1988 (**Figure 8**).

Annual Abundance Indices for Private

Final deviance tables are included in **Table 6**. The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive interviews) components were:

$$ProportionPositive = YEAR + SEASON$$

$$ln(CPUE) = YEAR + SEASON + YEAR * SEASON$$

For the binomial model, year and season were significant variables (**Table 6**).

Diagnostics for each component of the GLM are provided in **Figure 9** and **Figure 10**. The binomial model consistently estimated the proportion of positive interviews (**Figure 9A**). The proportion positive ranged from 0.19 to 0.7, and has generally remained between 0.37 and 0.6. Residual analysis of the binomial model showed no obvious patterns in the residuals by year (**Figure 9B**) or season (**Figure 9C**).

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 10A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals by year (**Figure 10C**) or season (**Figure 10D**).

Table 7 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of interviews. Nominal CPUE values fell within the 95% confidence interval of the standardized index (**Figure 11**). Relative abundance remained below the time series mean in the first few years of the index and increased to above the time series mean during the mid-1990s until 2010. The index showed a continuous decline from 2010 to the end of the time series. Relative abundance peaked in 2008, and was at the lowest value in 1987 (**Figure 11**).

Annual Abundance Indices for Combined Modes

Final deviance tables are included in **Table 8**. The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive interviews) components were:

$$ProportionPositive = YEAR + SEASON$$

$$ln(CPUE) = YEAR + MODE + SEASON + YEAR * SEASON + SEASON * MODE$$

For the binomial model, year and season were significant variables (**Table 8**).

Diagnostics for each component of the GLM are provided in **Figure 12** and **Figure 13**. The binomial model consistently estimated the proportion of positive interviews (**Figure 12A**). The proportion positive ranged from 0.26 to 0.82, and has generally remained between 0.38 and 0.66. Residual analysis of the binomial model showed no obvious patterns in the residuals by year (**Figure 13B**) or season (**Figure 13C**).

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 13A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals by year (**Figure 13C**), mode (**Figure 13D**) or season (**Figure 13E**).

Table 9 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of interviews. Nominal CPUE values fell within the 95% confidence interval of the standardized index, with the exception of the values in years 1986 (**Figure 14**). Relative abundance remained below the time series mean in the 1980s, increased to above the time series mean during most of the 1990s and 2000s. However, the index showed a continuous decline from 2011 to the end of the time series. Relative abundance peaked in 2005, and was at the lowest value in 2015 (**Figure 14**).

Comments on Adequacy for Assessment

The Charterboat and Private combined index presented in this working paper is based on improved methodology compared to the continuity approach for developing indices of abundance for Gulf reef fish stocks from the MRIP. The improved trip selection methodology yields similar indices for the charterboat (**Figure 15** and **Figure 16**) and private modes (**Figure 17** and **Figure 18**) used in SEDAR33. The index for Gag Grouper is associated with moderate variability with a mean CV of 0.18 (range: 0.12 – 0.39), which is lower compared to other Gulf species (e.g., Red Grouper CV range: 0.49 – 0.8; Sagarese and Rios 2018). Previous Gulf reef fish assessments have included this index because it contains one of the longest time series and has widespread spatial coverage compared to other indices.

Additional research is needed to explore alternative trip selection approaches which may be more appropriate for the Gulf of Mexico and South Atlantic recreational fisheries.

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Tables

Table 1. Association coefficients of other species with Gag Grouper for the Charterboat recreational fishery. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
1.365	Red Grouper	*Epinephelus morio*
1.244	Red Snapper	*Lutjanus campechanus*
1.155	White Grunt	*Haemulon plumieri*
0.844	Scamp	*Mycteroperca phenax*
0.716	Black Sea Bass	*Centropristis striata*
0.641	Gray Snapper	*Lutjanus griseus*
0.547	Inshore Lizardfish	*Synodus foetens*
0.544	Gulf Flounder	*Paralichthys albigutta*
0.506	Amberjack Genus	*Seriola spp.*
0.483	Bluefish	*Pomatomus saltatrix*
0.339	Gray Triggerfish	*Balistes capriscus*
0.283	Southern Puffer	*Sphoeroides nephelus*
0.244	Greater Amberjack	*Seriola dumerili*
0.170	Wahoo	*Acanthocybium solandri*
0.167	Blackfin Tuna	*Thunnus atlanticus*
0.142	Almaco Jack	*Seriola rivoliana*
0.124	Banded Rudderfish	*Seriola zonata*
0.082	Requiem Shark Genus	*Carcharhinus spp.*
0.030	Cobia	*Rachycentron canadum*
0.024	Hardhead Catfish	*Arius felis*
-0.007	Sheepshead	*Archosargus probatocephalus*
-0.048	Requiem Shark Family	*Carcharhinidae*
-0.051	Red Drum	*Sciaenops ocellatus*
-0.075	Atlantic Thread Herring	*Opisthonema oglinum*
-0.078	Little Tunny	*Euthynnus alletteratus*
-0.089	Round Scad	*Decapterus punctatus*
-0.142	Crevalle Jack	*Caranx hippos*
-0.159	King Mackerel	*Scomberomorus cavalla*

Coefficient	Common Name	Scientific Name
-0.167	Pinfish	*Lagodon rhomboides*
-0.177	Vermilion Snapper	*Rhomboplites aurorubens*
-0.195	Common Snook	*Centropomus undecimalis*
-0.225	Red Porgy	*Pagrus pagrus*
-0.257	Dolphin	*Coryphaena hippurus*
-0.262	Remora	*Remora remora*
-0.280	Blue Runner	*Caranx crysos*
-0.289	Whitebone Porgy	*Calamus leucosteus*
-0.299	Lane Snapper	*Lutjanus synagris*
-0.321	Spanish Mackerel	*Scomberomorus maculatus*
-0.389	Ladyfish	*Elops saurus*
-0.411	Littlehead Porgy	*Calamus proridens*
-0.411	Littlehead Porgy	*Calamus proridens*
-0.524	Great Barracuda	*Sphyraena barracuda*
-0.560	Sand Perch	*Diplectrum formosum*
-0.582	Herring Family	*Clupeidae*
-0.641	Bank Sea Bass	*Centropristis ocyurus*
-0.759	Tomtate	*Haemulon aurolineatum*
-0.793	Remora Family	*Echeneidae*
-0.932	Spotted Seatrout	*Cynoscion nebulosus*

Table 2. Association coefficients of other species with Gag Grouper for the Private recreational fishery. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
1.329	Red Grouper	*Epinephelus morio*
0.647	White Grunt	*Haemulon plumieri*
0.556	Cobia	*Rachycentron canadum*
0.509	Gray Snapper	*Lutjanus griseus*
0.485	Red Snapper	*Lutjanus campechanus*
0.438	Black Sea Bass	*Centropristis striata*
0.436	Gulf Flounder	*Paralichthys albigutta*
0.343	Gray Triggerfish	*Balistes capriscus*
0.312	Scaled Sardine	*Harengula jaguana*
0.239	Inshore Lizardfish	*Synodus foetens*
0.213	Greater Amberjack	*Seriola dumerili*
0.208	Southern Puffer	*Sphoeroides nephelus*
0.157	Requiem Shark Family	*Carcharhinidae*
-0.075	Pigfish	*Orthopristis chrysoptera*
-0.081	Remora Family	*Echeneidae*
-0.092	King Mackerel	*Scomberomorus cavalla*
-0.121	Tomtate	*Haemulon aurolineatum*
-0.150	Sheepshead	*Archosargus probatocephalus*
-0.168	Spanish Mackerel	*Scomberomorus maculatus*
-0.196	Bluefish	*Pomatomus saltatrix*
-0.219	Requiem Shark Genus	*Carcharhinus spp.*
-0.283	Pinfish	*Lagodon rhomboides*
-0.313	Blue Runner	*Caranx crysos*
-0.334	Lane Snapper	*Lutjanus synagris*
-0.362	Blacktip Shark	*Carcharhinus limbatus*
-0.416	Crevalle Jack	*Caranx hippos*
-0.430	Vermilion Snapper	*Rhomboplites aurorubens*
-0.453	Ladyfish	*Elops saurus*
-0.457	Stingray Genus	*Dasyatis spp.*

Coefficient	Common Name	Scientific Name
-0.467	Little Tunny	*Euthynnus alletteratus*
-0.559	Sand Perch	*Diplectrum formosum*
-0.599	Bonnethead	*Sphyrna tiburo*
-0.638	Sand Seatrout	*Cynoscion arenarius*
-0.670	Common Snook	*Centropomus undecimalis*
-0.850	Hardhead Catfish	*Arius felis*
-0.875	Gafftopsail Catfish	*Bagre marinus*
-1.038	Spotted Seatrout	*Cynoscion nebulosus*
-1.057	Red Drum	*Sciaenops ocellatus*

Table 3. Association coefficients of other species with Gag Grouper for the Charterboat and Private combined recreational fishery. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
1.396	Red Grouper	*Epinephelus morio*
1.019	Red Snapper	*Lutjanus campechanus*
0.924	Scamp	*Mycteroperca phenax*
0.775	White Grunt	*Haemulon plumieri*
0.592	Gray Snapper	*Lutjanus griseus*
0.525	Gulf Flounder	*Paralichthys albigutta*
0.466	Black Sea Bass	*Centropristis striata*
0.414	Gray Triggerfish	*Balistes capriscus*
0.354	Cobia	*Rachycentron canadum*
0.306	Inshore Lizardfish	*Synodus foetens*
0.293	Almaco Jack	*Seriola rivoliana*
0.293	Greater Amberjack	*Seriola dumerili*
0.265	Southern Puffer	*Sphoeroides nephelus*
0.235	Scaled Sardine	*Harengula jaguana*
0.142	Bluefish	*Pomatomus saltatrix*
0.036	Atlantic Thread Herring	*Opisthonema oglinum*
0.022	Requiem Shark Family	*Carcharhinidae*
-0.005	King Mackerel	*Scomberomorus cavalla*
-0.083	Sheepshead	*Archosargus probatocephalus*
-0.089	Little Tunny	*Euthynnus alletteratus*
-0.121	Pigfish	*Orthopristis chrysoptera*
-0.133	Red Porgy	*Pagrus pagrus*
-0.152	Vermilion Snapper	*Rhomboplites aurorubens*
-0.156	Remora	*Remora remora*
-0.161	Spanish Mackerel	*Scomberomorus maculatus*
-0.183	Requiem Shark Genus	*Carcharhinus spp.*
-0.215	Great Barracuda	*Sphyraena barracuda*
-0.268	Blacktip Shark	*Carcharhinus limbatus*
-0.270	Lane Snapper	*Lutjanus synagris*

Coefficient	Common Name	Scientific Name
-0.289	Round Scad	*Decapterus punctatus*
-0.294	Blue Runner	*Caranx crysos*
-0.333	Pinfish	*Lagodon rhomboides*
-0.341	Dolphin	*Coryphaena hippurus*
-0.349	Crevalle Jack	*Caranx hippos*
-0.381	Stingray Genus	*Dasyatis spp.*
-0.414	Remora Family	*Echeneidae*
-0.439	Ladyfish	*Elops saurus*
-0.479	Bonnethead	*Sphyrna tiburo*
-0.511	Common Snook	*Centropomus undecimalis*
-0.569	Tomtate	*Haemulon aurolineatum*
-0.608	Sand Seatrout	*Cynoscion arenarius*
-0.614	Sand Perch	*Diplectrum formosum*
-0.763	Hardhead Catfish	*Arius felis*
-0.808	Red Drum	*Sciaenops ocellatus*
-0.834	Gafftopsail Catfish	*Bagre marinus*
-1.008	Spotted Seatrout	*Cynoscion nebulosus*

Table 4. Deviance tables for the regression models for Gag Grouper in the Charterboat recreational fishery. The table shows the order of the factors as they were sequentially added to each model. Fit diagnostics listed for each factor were the diagnostics from a model that included that factor and all of the factors listed above it in the tables below.

Factor	DF	Deviance	Residual DF	Residual Deviance	AIC	Deviance Reduced	Log likelihood	Likelihood Ratio Test
Binomial								
Null	1	11,512	8,857	11,512	11,512	-	-5,756	-
Year	33	10,359	8,852	1,153	10,359	10%	-5,179	1153.4
Season	5	10,184	8,818	175	10,184	2%	-5,092	175
Hrsf	4	10,059	8,815	125	10,059	1%	-5,029	125.2
Year*Season	148	9,635	8,659	423	9,635	2%	-4,817	423.8
Lognormal								
Null	1	9,092	5,722	9,092	18,890	-	-9,445	-
Year	33	8,517	5,689	574	18,517	6%	-9,258	373.6
Season	5	7,851	5,684	666	18,050	8%	-9,025	466.4
Year*Season	148	7,339	5,536	511	17,665	4%	-8,832	385.6

Table 5. Numbers (N) of total and positive interviews, proportion of positive interviews (PPT), relative nominal CPUE, and standardized abundance index statistics for Gag Grouper in the Charterboat recreational fishery.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1986	78	39	0.50	1.16	1.11	0.646	1.90	0.28
1987	43	22	0.51	0.51	0.49	0.246	0.96	0.35
1988	21	5	0.24	0.24	0.20	0.057	0.68	0.69
1989	33	20	0.61	0.58	0.41	0.211	0.80	0.34
1990	36	21	0.58	2.20	0.58	0.217	1.54	0.52
1991	14	4	0.29	0.44	0.56	0.149	2.07	0.74
1992	48	21	0.44	1.03	1.31	0.675	2.55	0.34
1993	42	19	0.45	1.22	1.34	0.689	2.62	0.34
1994	50	20	0.40	0.95	0.65	0.327	1.31	0.36
1995	32	28	0.88	3.39	3.13	1.872	5.23	0.26
1996	28	22	0.79	1.42	2.49	1.451	4.29	0.28
1997	112	77	0.69	1.14	0.86	0.555	1.34	0.22
1998	297	250	0.84	1.67	1.53	1.085	2.17	0.17
1999	474	383	0.81	1.33	1.42	1.005	1.99	0.17
2000	496	312	0.63	0.75	0.68	0.443	1.04	0.22
2001	406	305	0.75	1.02	0.91	0.615	1.35	0.20
2002	505	376	0.74	1.20	1.18	0.803	1.73	0.19
2003	689	565	0.82	1.45	1.60	1.119	2.29	0.18
2004	906	713	0.79	1.72	1.89	1.329	2.70	0.18
2005	726	619	0.85	1.62	2.07	1.449	2.96	0.18
2006	388	259	0.67	0.77	0.79	0.513	1.21	0.22
2007	350	165	0.47	0.48	0.52	0.317	0.86	0.26
2008	298	187	0.63	1.03	0.95	0.604	1.49	0.23
2009	277	169	0.61	0.96	1.06	0.661	1.70	0.24
2010	258	161	0.62	0.96	1.06	0.666	1.68	0.23
2011	325	173	0.53	0.65	0.65	0.404	1.05	0.24
2012	369	207	0.56	0.76	0.90	0.566	1.43	0.23
2013	141	73	0.52	0.71	0.57	0.309	1.04	0.31
2014	317	109	0.34	0.36	0.49	0.275	0.89	0.30

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
2015	241	70	0.29	0.36	0.38	0.199	0.72	0.33
2016	302	119	0.39	0.34	0.45	0.255	0.80	0.29
2017	216	79	0.37	0.50	0.47	0.254	0.88	0.32
2018	175	71	0.41	0.69	0.79	0.426	1.48	0.32
2019	165	60	0.36	0.42	0.50	0.250	0.98	0.35

Table 6. Deviance tables for the regression models for Gag Grouper in the Private recreational fishery. The table shows the order of the factors as they were sequentially added to each model. Fit diagnostics listed for each factor were the diagnostics from a model that included that factor and all of the factors listed above it in the tables below.

Factor	DF	Deviance	Residual DF	Residual Deviance	AIC	Deviance Reduced	Log likelihood	Likelihood Ratio Test
Binomial								
Null	1	17,685	12,758	17,685	17,685	-	-8,842	-
Year	33	16,598	12,725	1,087	16,598	6%	-8,299	1087.6
Season	5	16,326	12,720	271	16,327	2%	-8,163	271
Lognormal								
Null	1	6,587	6,298	6,587	18,157	-	-9,078	-
Year	33	6,343	6,265	243	17,920	3%	-8,960	237.2
Season	5	6,249	6,260	94	17,826	1%	-8,913	94.2
Year*Season	160	5,992	6,100	256	17,562	2%	-8,781	264.2

Table 7. Numbers (N) of total and positive interviews, proportion of positive interviews (PPT), relative nominal CPUE, and standardized abundance index statistics for Gag Grouper in the Private recreational fishery.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1986	101	38	0.38	0.84	1.12	0.60	2.09	0.32
1987	121	23	0.19	0.22	0.28	0.12	0.64	0.44
1988	56	21	0.38	0.68	0.66	0.28	1.55	0.44
1989	195	37	0.19	0.30	0.30	0.15	0.60	0.36
1990	149	40	0.27	0.88	0.66	0.35	1.26	0.33
1991	188	59	0.31	0.85	0.72	0.42	1.25	0.28
1992	324	110	0.34	0.81	0.65	0.43	1.00	0.21
1993	328	136	0.41	0.92	0.92	0.63	1.33	0.19
1994	339	161	0.47	1.11	1.10	0.78	1.56	0.17
1995	284	166	0.58	1.69	1.56	1.13	2.16	0.16
1996	288	155	0.54	1.05	1.21	0.86	1.69	0.17
1997	254	158	0.62	1.53	1.56	1.12	2.16	0.16
1998	460	298	0.65	1.61	1.59	1.22	2.07	0.13
1999	712	371	0.52	1.08	1.03	0.79	1.34	0.13
2000	480	259	0.54	0.96	0.97	0.72	1.29	0.14
2001	576	310	0.54	1.15	1.08	0.82	1.42	0.14
2002	604	323	0.54	1.19	1.12	0.85	1.47	0.14
2003	575	367	0.64	1.59	1.58	1.23	2.03	0.13
2004	705	455	0.64	1.60	1.56	1.23	1.98	0.12
2005	395	276	0.70	1.48	1.53	1.18	2.00	0.13
2006	243	168	0.69	1.53	1.34	0.99	1.83	0.15
2007	335	231	0.69	1.80	1.72	1.30	2.28	0.14
2008	574	382	0.67	1.89	1.83	1.43	2.33	0.12
2009	460	270	0.59	1.26	1.31	0.99	1.73	0.14
2010	358	205	0.57	1.16	1.34	0.98	1.83	0.16
2011	399	187	0.47	0.89	0.92	0.67	1.28	0.16
2012	363	136	0.38	0.61	0.59	0.40	0.86	0.19
2013	448	169	0.38	0.53	0.59	0.42	0.84	0.18
2014	637	209	0.33	0.42	0.49	0.35	0.68	0.17

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
2015	472	106	0.22	0.27	0.32	0.20	0.49	0.22
2016	406	105	0.26	0.40	0.48	0.31	0.74	0.22
2017	411	154	0.38	0.63	0.61	0.42	0.88	0.19
2018	274	127	0.46	0.59	0.73	0.50	1.07	0.19
2019	245	87	0.35	0.46	0.53	0.34	0.85	0.23

Table 8. Deviance tables for the regression models for Gag Grouper in the Charterboat and Private combined recreational fishery. The table shows the order of the factors as they were sequentially added to each model. Fit diagnostics listed for each factor were the diagnostics from a model that included that factor and all of the factors listed above it in the tables below.

Factor	DF	Deviance	Residual DF	Residual Deviance	AIC	Deviance Reduced	Log likelihood	Likelihood Ratio Test
Binomial								
Null	1	29,067	21,234	29,067	29,067	-	-14,533	-
Year	33	26,789	21,201	2,277	26,789	8%	-13,394	2277.8
Season	5	26,295	21,196	494	26,295	2%	-13,147	494.4
Lognormal								
Null	1	17,142	12,017	17,142	38,373	-	-19,186	-
Year	33	16,489	11,984	653	37,907	4%	-18,953	466.8
Mode	1	15,453	11,983	1,036	37,126	6%	-18,563	780.2
Season	5	14,749	11,978	703	36,567	5%	-18,283	559.8
Year*Season	162	14,279	11,816	470	36,177	2%	-18,088	389.2
Season*Mode	5	14,112	11,811	166	36,036	1%	-18,018	141.2

Table 9. Numbers (N) of total and positive interviews, proportion of positive interviews (PPT), relative nominal CPUE, and standardized abundance index statistics for Gag Grouper in the Charterboat and Private combined recreational fishery.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1,986	277	160	0.58	1.18	1.70	1.20	2.43	0.18
1,987	179	58	0.32	0.33	0.36	0.21	0.63	0.29
1,988	75	28	0.37	0.52	0.49	0.23	1.06	0.39
1,989	207	53	0.26	0.35	0.32	0.17	0.58	0.31
1,990	153	56	0.37	1.24	0.72	0.41	1.29	0.30
1,991	160	51	0.32	0.96	0.71	0.39	1.29	0.31
1,992	333	132	0.40	1.01	0.79	0.52	1.19	0.21
1,993	325	146	0.45	1.08	1.00	0.68	1.48	0.20
1,994	301	150	0.50	1.29	1.10	0.76	1.60	0.19
1,995	277	174	0.63	1.82	1.58	1.12	2.21	0.17
1,996	256	157	0.61	1.37	1.36	0.96	1.92	0.17
1,997	330	223	0.68	1.38	1.23	0.90	1.69	0.16
1,998	710	518	0.73	1.64	1.57	1.21	2.03	0.13
1,999	1,134	754	0.66	1.23	1.24	0.96	1.60	0.13
2,000	921	545	0.59	0.86	0.90	0.68	1.20	0.14
2,001	898	589	0.66	1.08	1.08	0.82	1.41	0.14
2,002	1,023	666	0.65	1.21	1.23	0.94	1.60	0.13
2,003	1,224	917	0.75	1.55	1.77	1.39	2.27	0.12
2,004	1,631	1,196	0.73	1.61	1.69	1.33	2.15	0.12
2,005	1,100	892	0.81	1.54	1.86	1.46	2.38	0.12
2,006	632	424	0.67	1.01	1.08	0.81	1.44	0.14
2,007	745	415	0.56	1.08	1.12	0.83	1.51	0.15
2,008	898	599	0.67	1.63	1.57	1.21	2.05	0.13
2,009	748	455	0.61	1.19	1.20	0.90	1.61	0.14
2,010	642	374	0.58	1.05	1.19	0.88	1.62	0.15
2,011	766	380	0.50	0.79	0.84	0.62	1.15	0.16
2,012	755	375	0.50	0.74	0.77	0.56	1.07	0.16
2,013	584	230	0.39	0.54	0.54	0.38	0.78	0.18
2,014	930	320	0.34	0.39	0.45	0.32	0.63	0.17

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
2,015	745	175	0.23	0.27	0.30	0.20	0.45	0.21
2,016	757	225	0.30	0.33	0.45	0.30	0.66	0.20
2,017	655	240	0.37	0.64	0.57	0.39	0.82	0.18
2,018	452	198	0.44	0.64	0.66	0.45	0.96	0.19
2,019	412	144	0.35	0.45	0.53	0.34	0.82	0.22

Figures

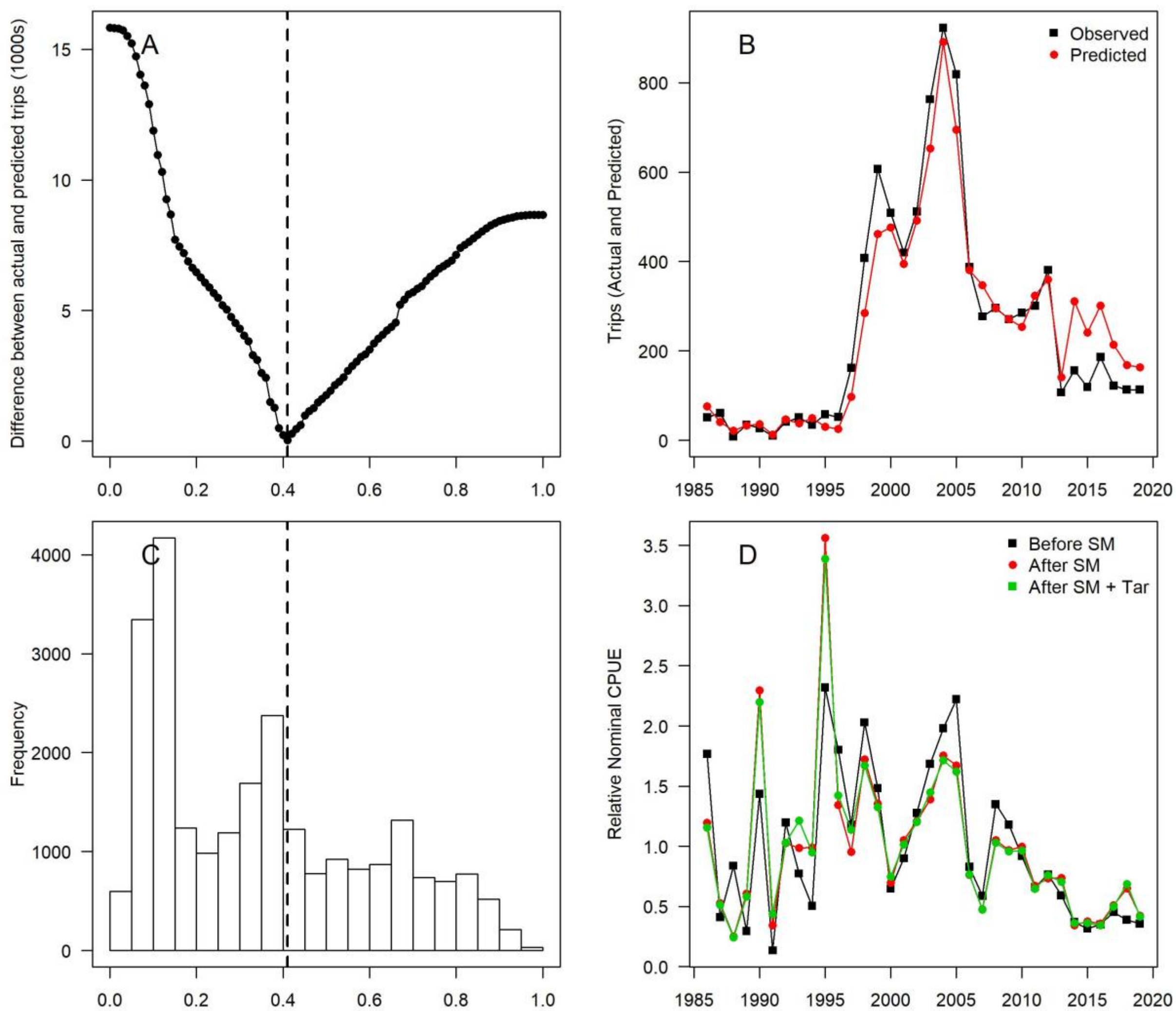

Figure 1. Stephens and MacCall (2004) trip selection diagnostics for the Charterboat recreational fishery. (A) The difference between the number of records in which Gag Grouper are observed and the number in which they are predicted to occur for each probability threshold; (B) the number of actual and predicted interviews; (C) Histogram of probabilities generated by the species-based regression; and (D) Nominal CPUE before ("Before SM") and after ("After SM") Stephens and MacCall (2004) trip selection ("After SM + Tar" = also includes all interviews where the target species was caught). The dashed vertical line indicates the critical value where false prediction is minimized.

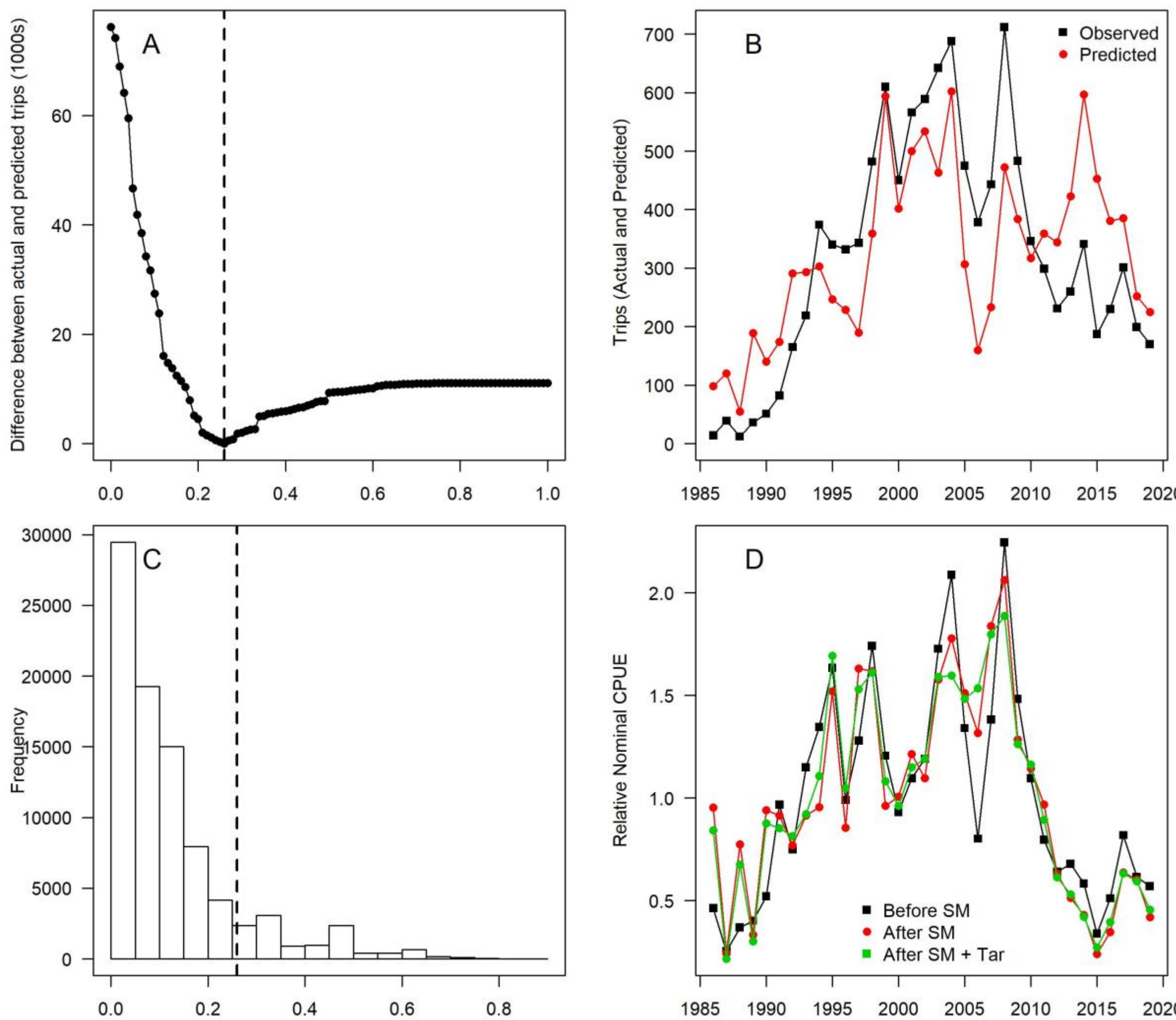

Figure 2. Stephens and MacCall (2004) trip selection diagnostics for the Private recreational fishery. (A) The difference between the number of records in which Gag Grouper are observed and the number in which they are predicted to occur for each probability threshold; (B) the number of actual and predicted interviews; (C) Histogram of probabilities generated by the species-based regression; and (D) Nominal CPUE before (“Before SM”) and after (“After SM”) Stephens and MacCall (2004) trip selection (“After SM + Tar” = also includes all interviews where the target species was caught). The dashed vertical line indicates the critical value where false prediction is minimized.

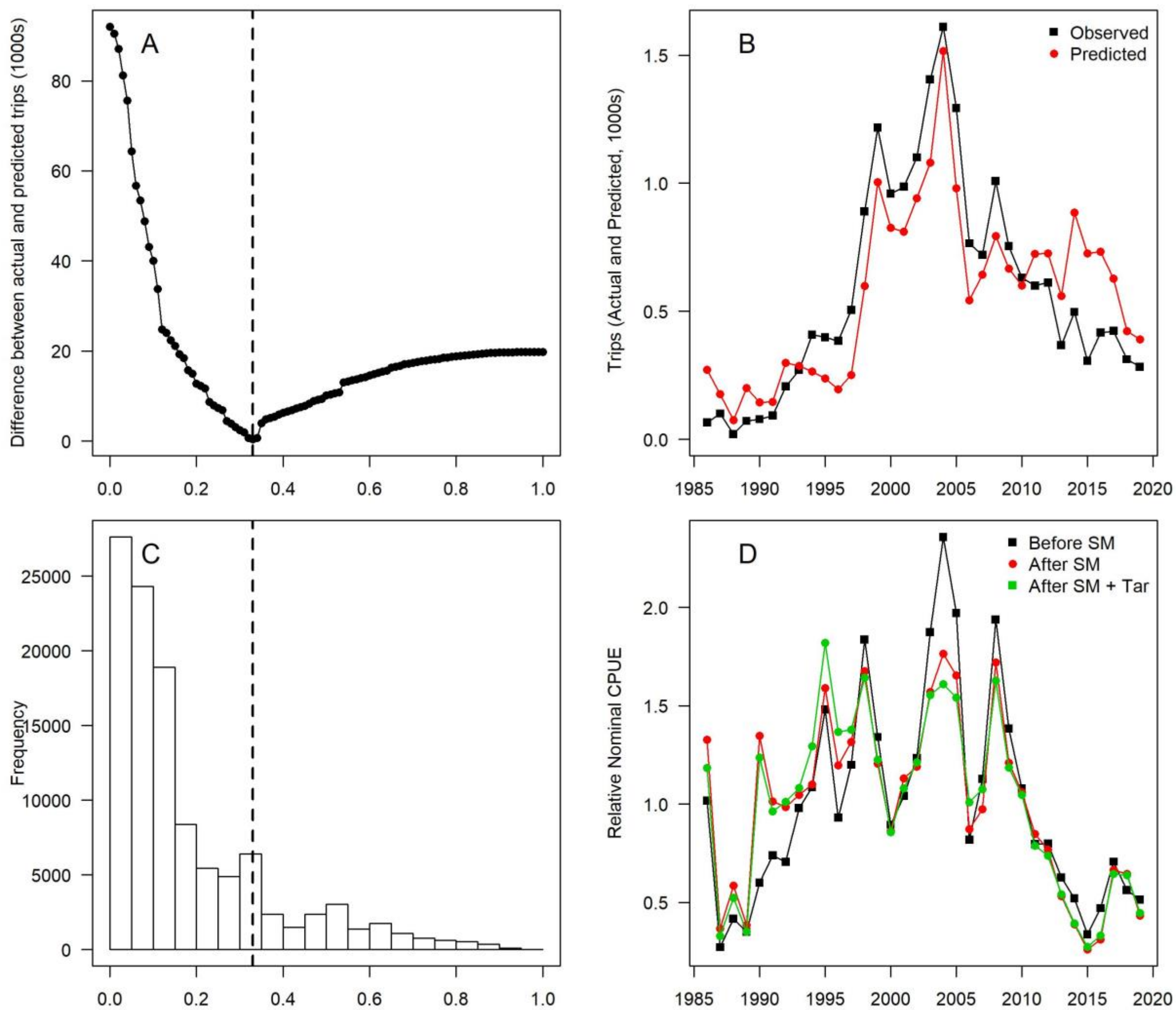

Figure 3. Stephens and MacCall (2004) trip selection diagnostics for the Charterboat and Private combined recreational fishery. (A) The difference between the number of records in which Gag Grouper are observed and the number in which they are predicted to occur for each probability threshold; (B) the number of actual and predicted interviews; (C) Histogram of probabilities generated by the species-based regression; and (D) Nominal CPUE before (“Before SM”) and after (“After SM”) Stephens and MacCall (2004) trip selection (“After SM + Tar” = also includes all interviews where the target species was caught). The dashed vertical line indicates the critical value where false prediction is minimized.

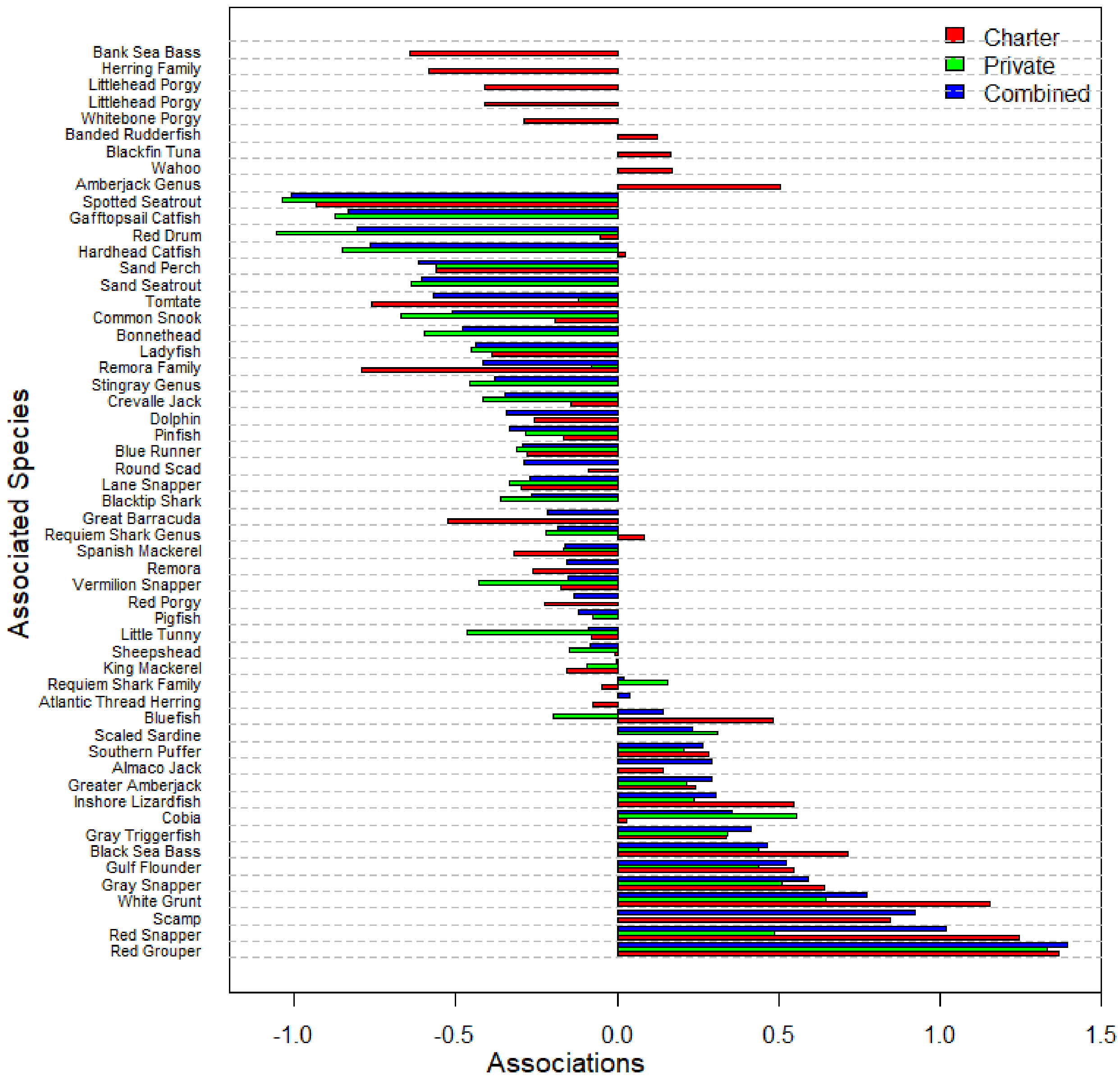

Figure 4. Association coefficients of other species with Gag Grouper across recreational fishing modes in the Gulf of Mexico. Positive numbers indicate a positive correlation.

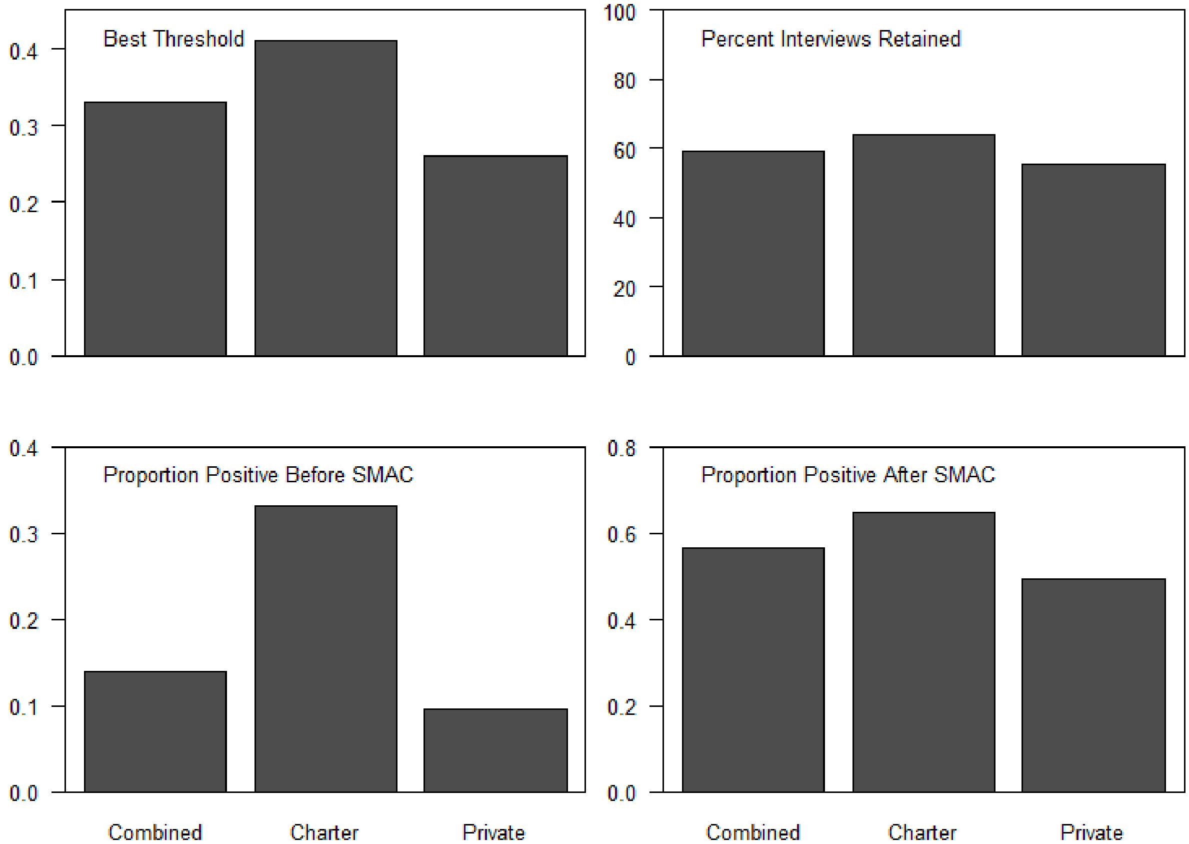

Figure 5. Stephens and MacCall (2004) statistics across recreational fishing modes for associations with Gag Grouper.

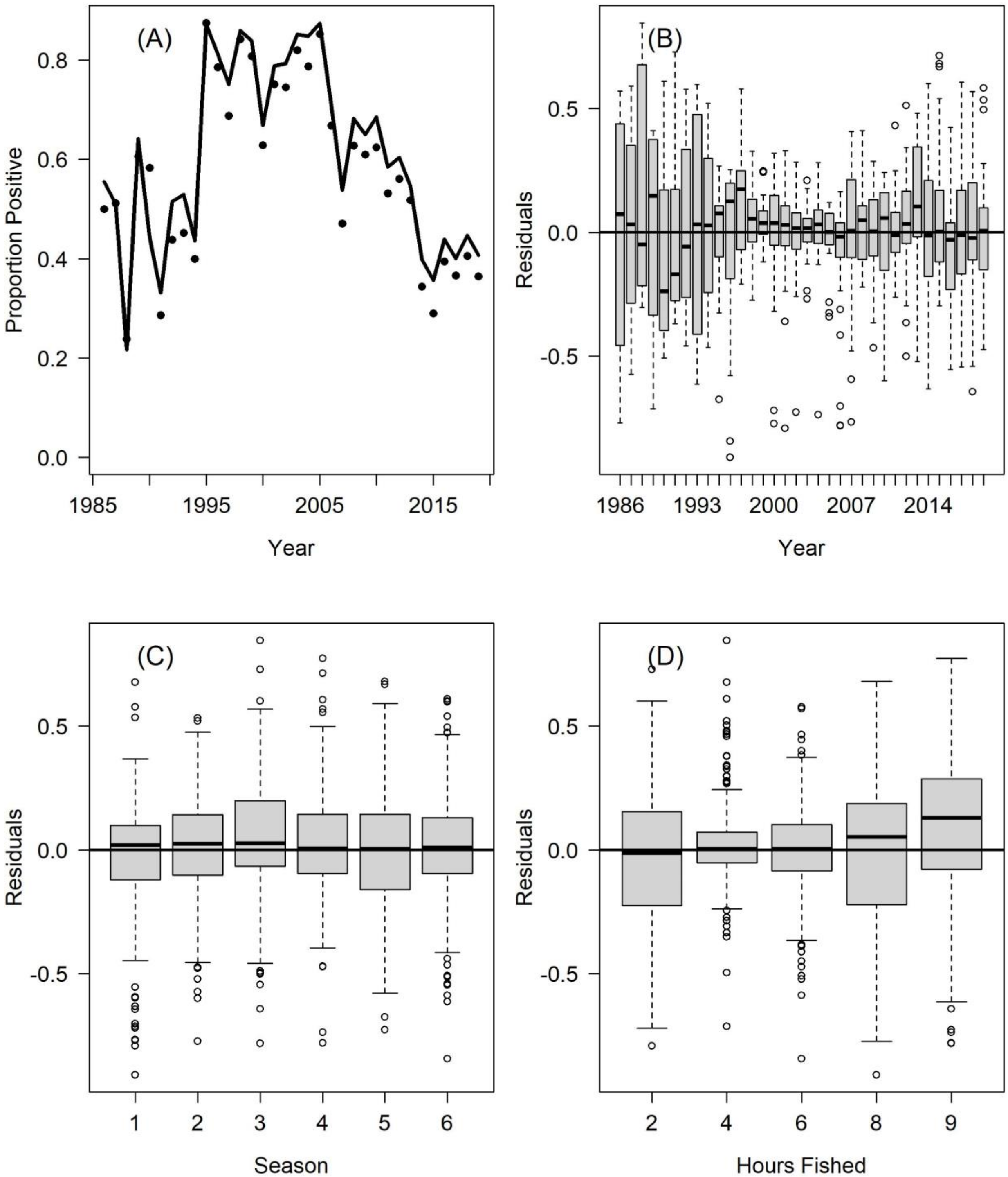

Figure 6. Diagnostic plots for the binomial model for Gag Grouper for the Charterboat recreational fishery. Shown here are the predicted (solid line) and observed proportion of positive interviews by year (A) and the residuals from the binomial model by year (B), season (C), and hours fished (D).

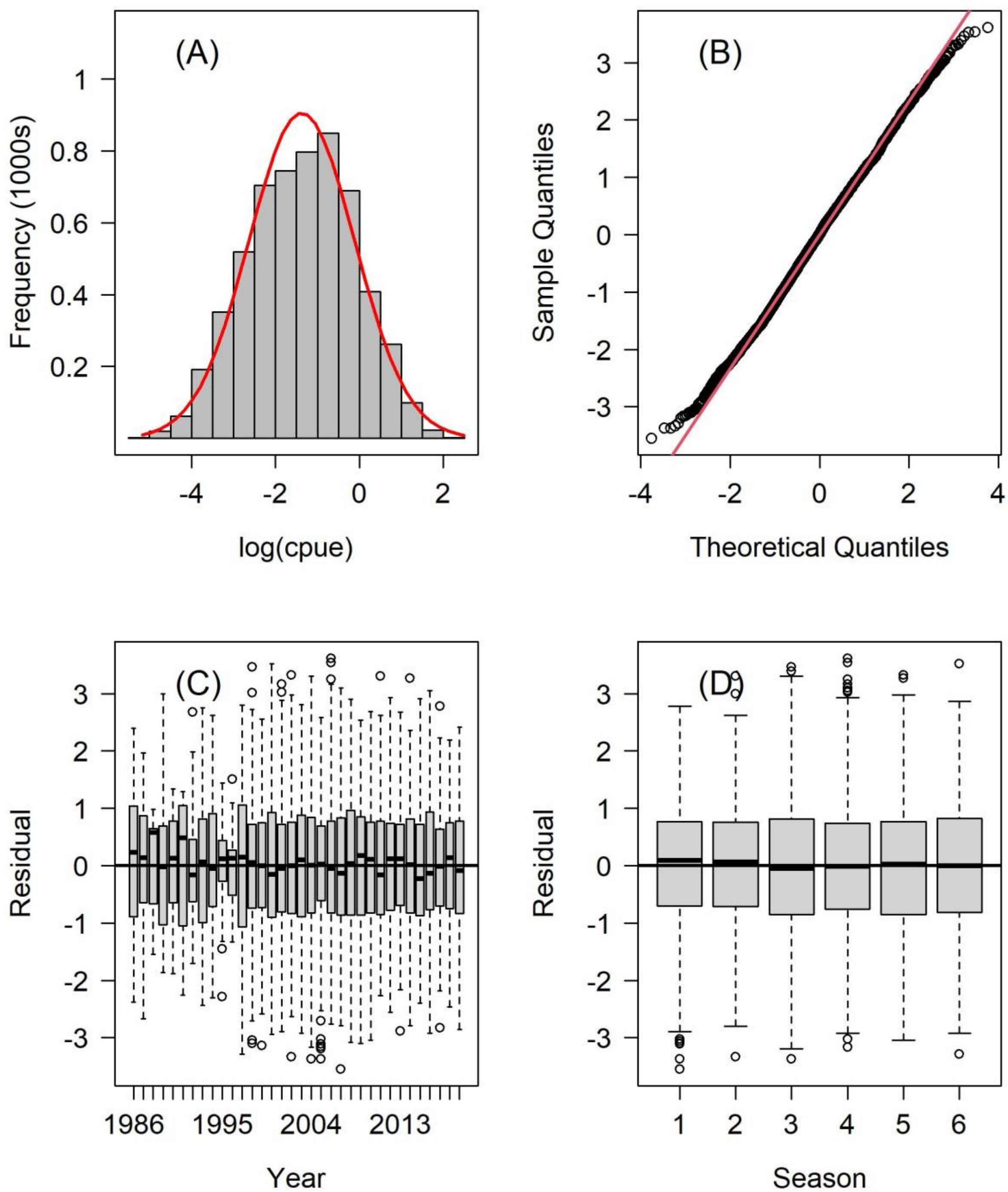

Figure 7. Diagnostic plots for the lognormal model of catch rates on positive interviews for Gag Grouper for the Charterboat recreational fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C) and season (D). The red lines represent the expected normal distribution.

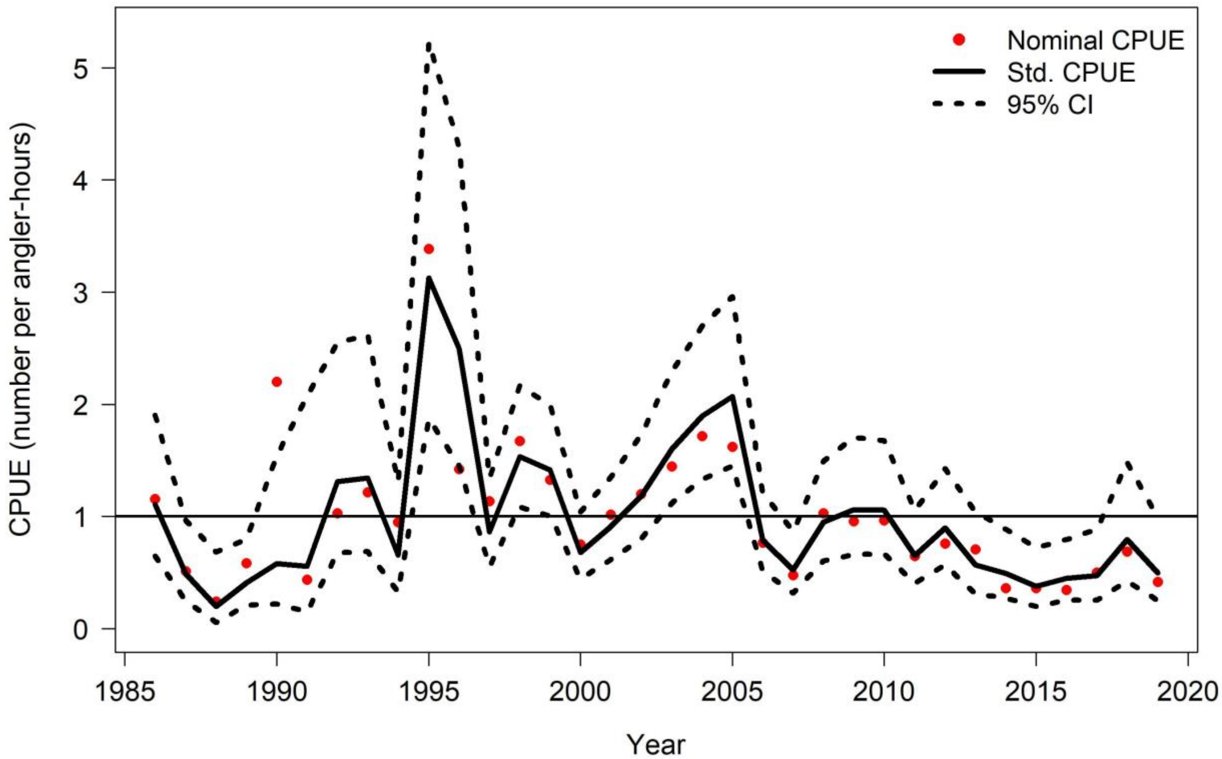

Figure 8. Standardized index with 95% confidence interval, and nominal CPUE for Gag Grouper for the Charterboat recreational fishery. The index was scaled to the mean value of the entire time series.

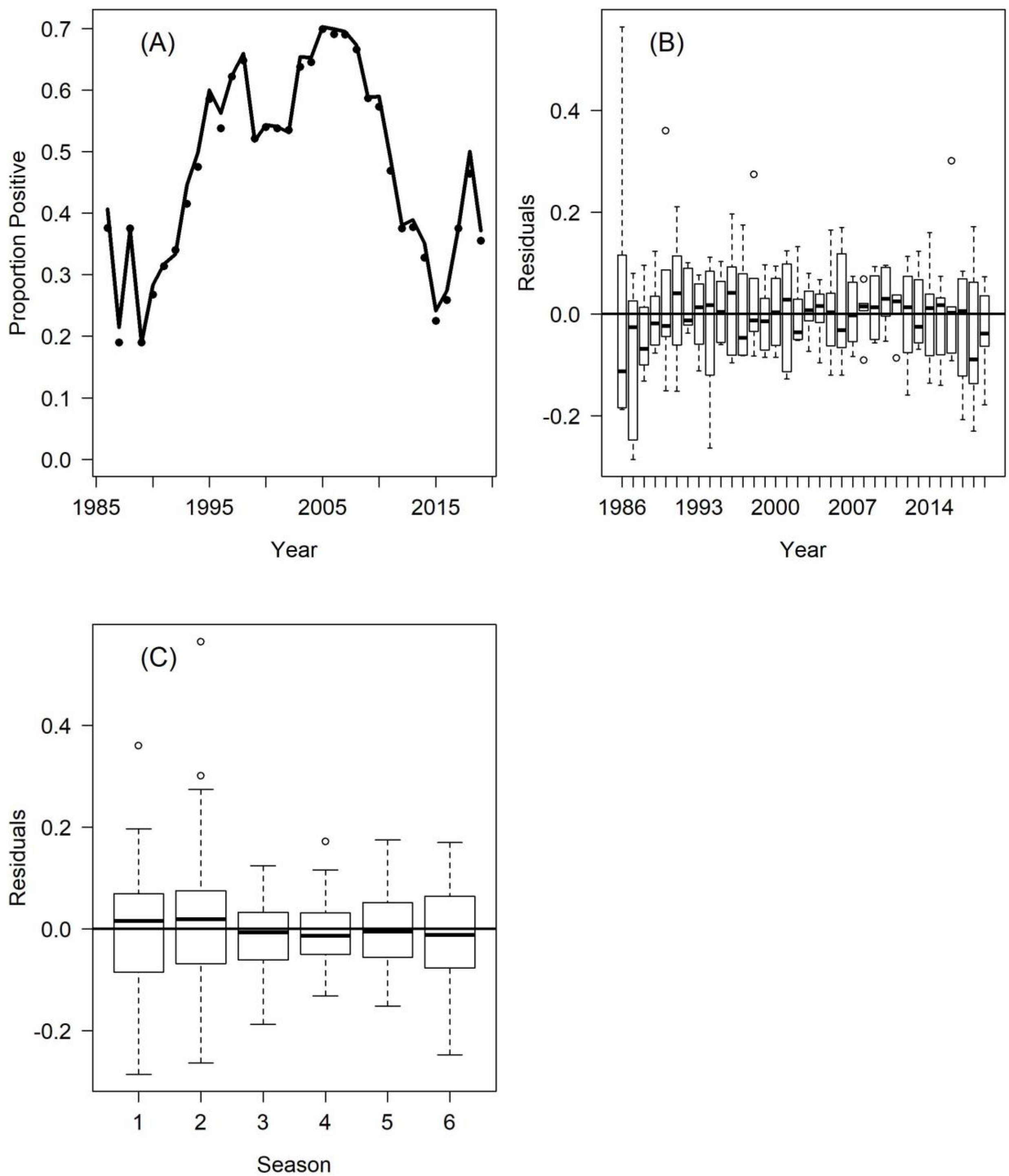

Figure 9. Diagnostic plots for the binomial model for Gag Grouper for the Private recreational fishery. Shown here are the predicted (solid line) and observed proportion of positive interviews by year (A) and the residuals from the binomial model by year (B) and season (C).

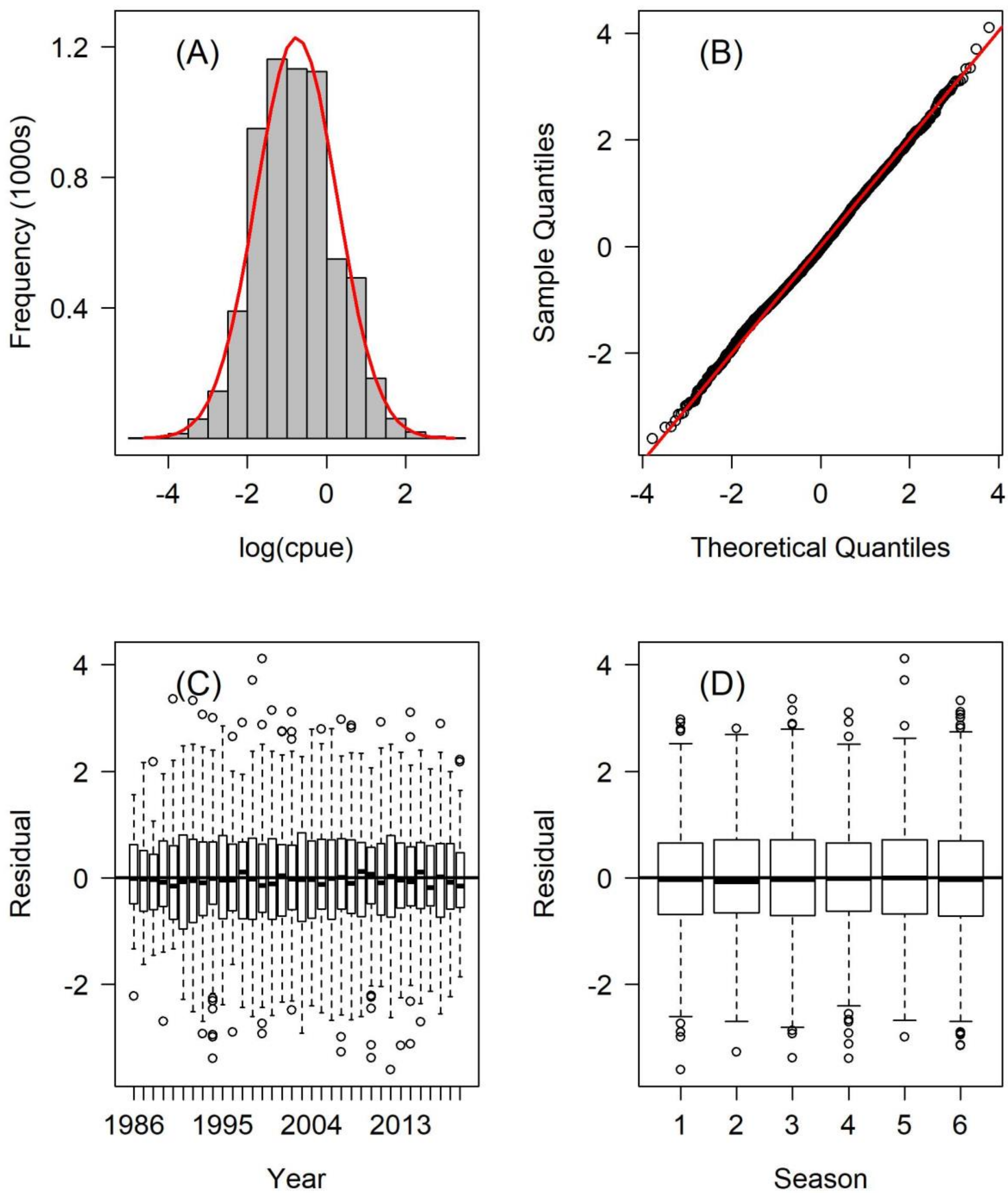

Figure 10. Diagnostic plots for the lognormal model of catch rates on positive interviews for Gag Grouper for the Private recreational fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C) and season (D). The red lines represent the expected normal distribution.

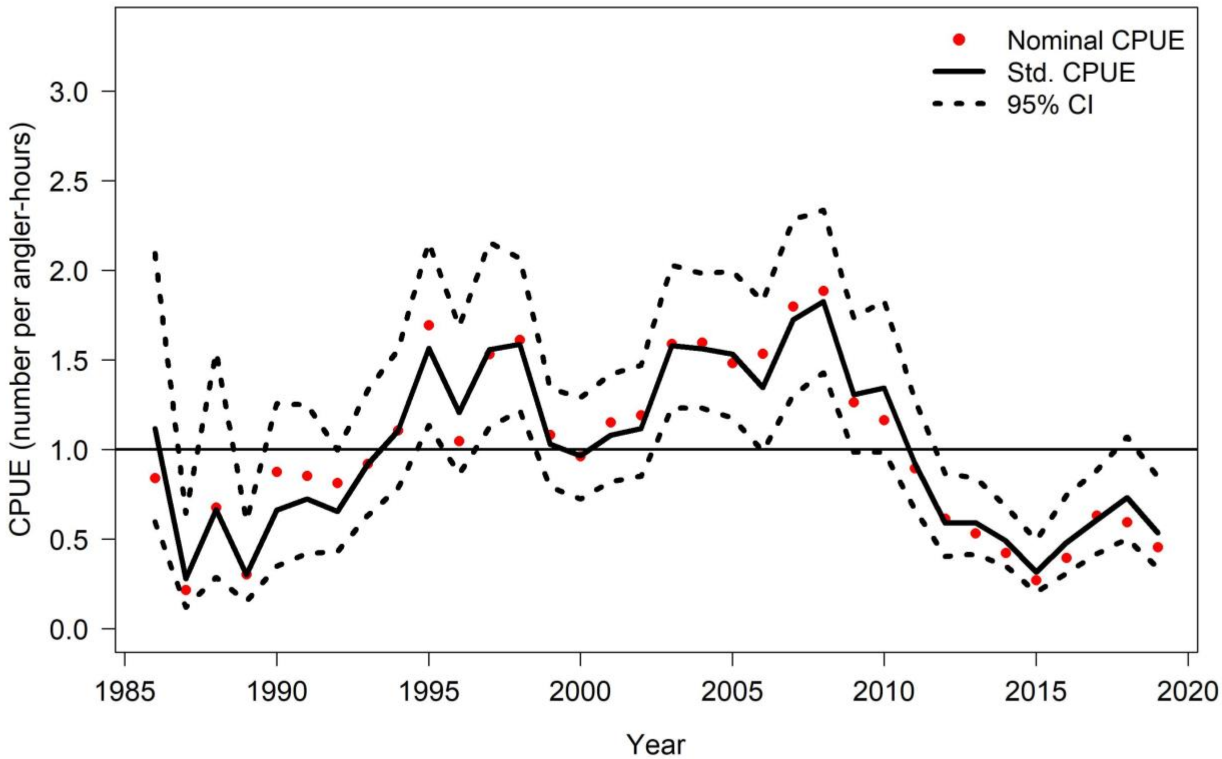

Figure 11. Standardized index with 95% confidence interval, and nominal CPUE for Gag Grouper for the Private recreational fishery. The index was scaled to the mean value of the entire time series.

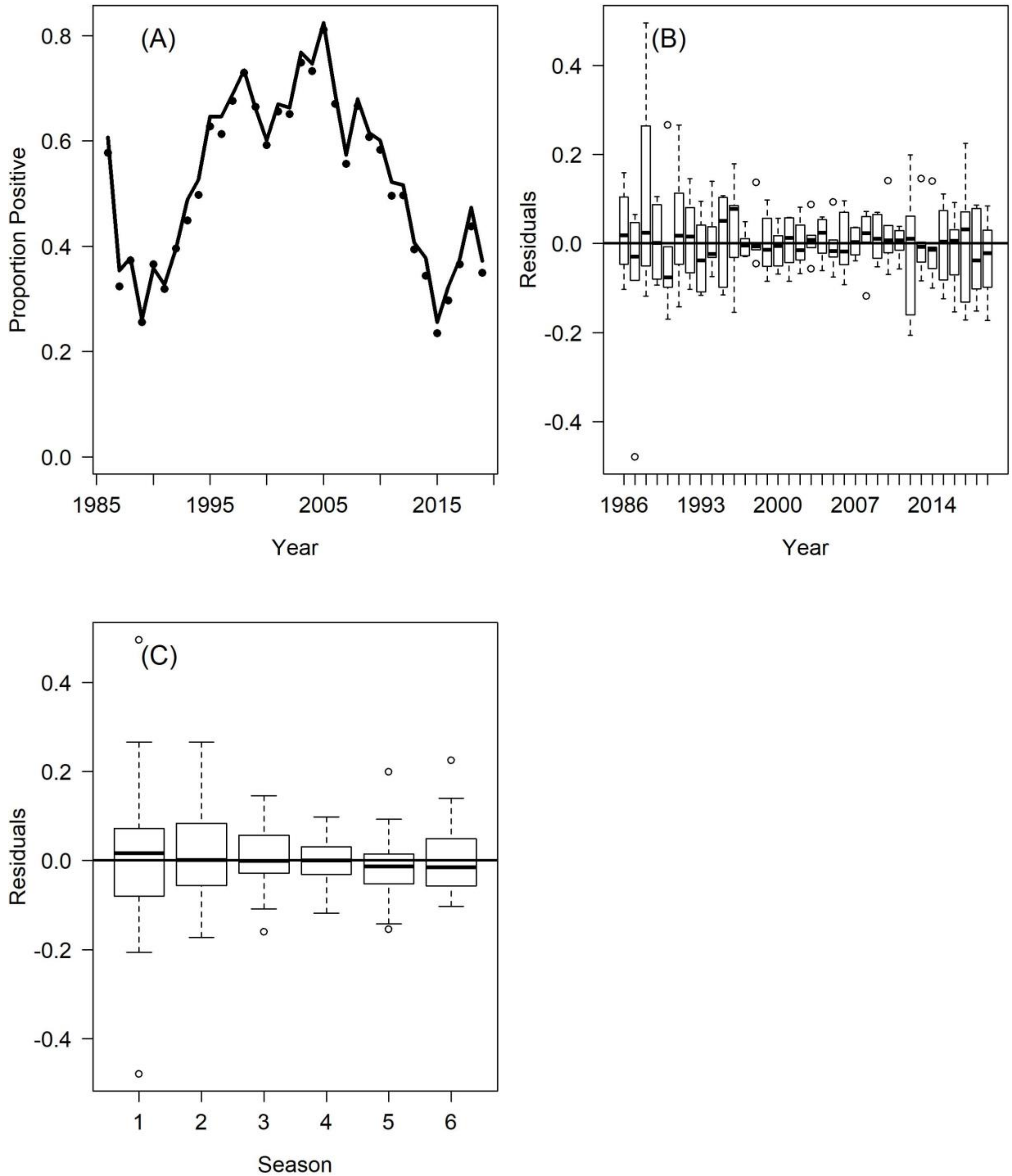

Figure 12. Diagnostic plots for the binomial model for Gag Grouper in the Charterboat and Private combined recreational fishery. Shown here are the predicted (solid line) and observed proportion of positive interviews by year (A) and the residuals from the binomial model by year (B) and season (C).

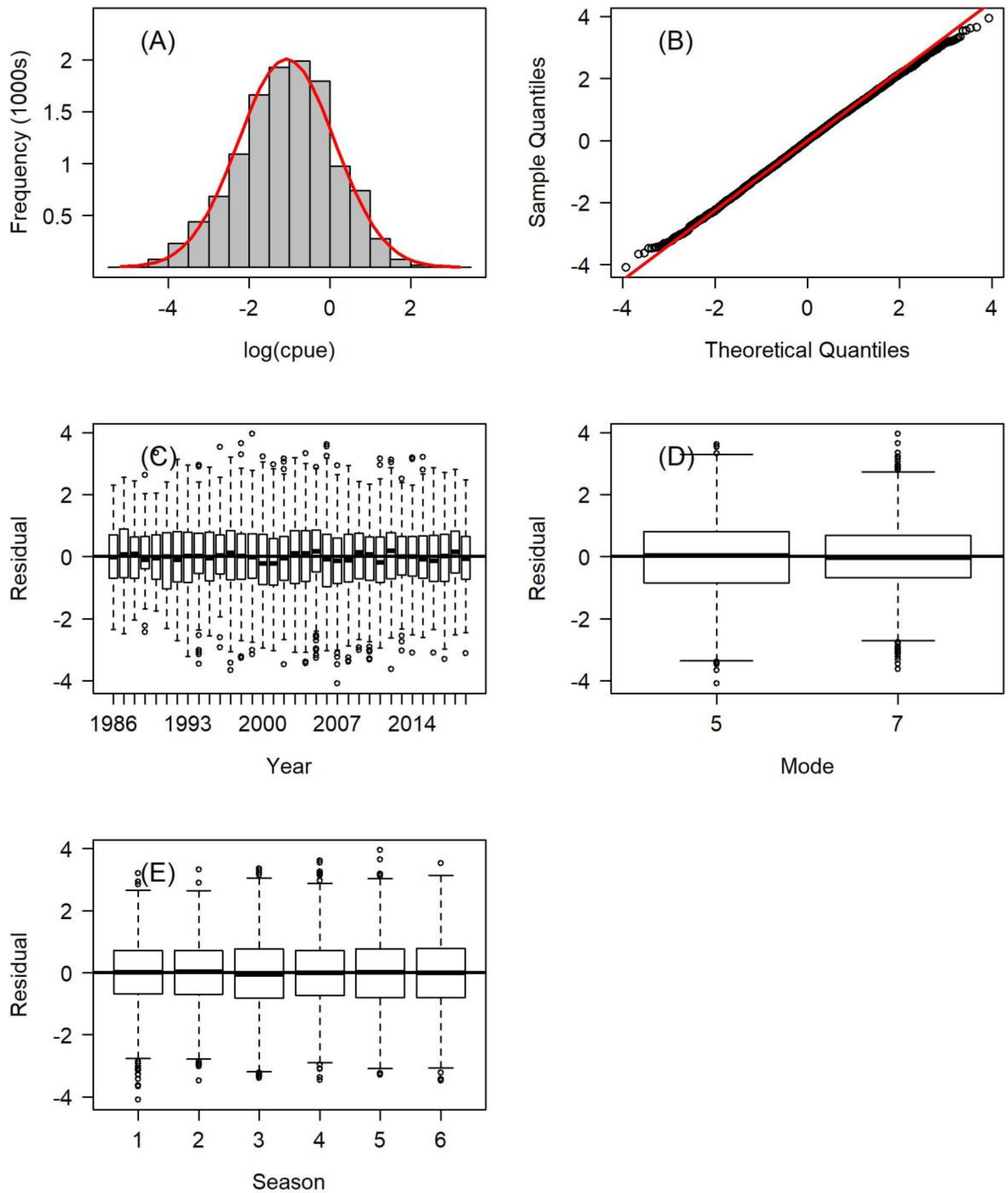

Figure 13. Diagnostic plots for the lognormal model of catch rates on positive interviews for Gag Grouper in the Charterboat and Private combined recreational fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C), mode (D), and season (E). The red lines represent the expected normal distribution.

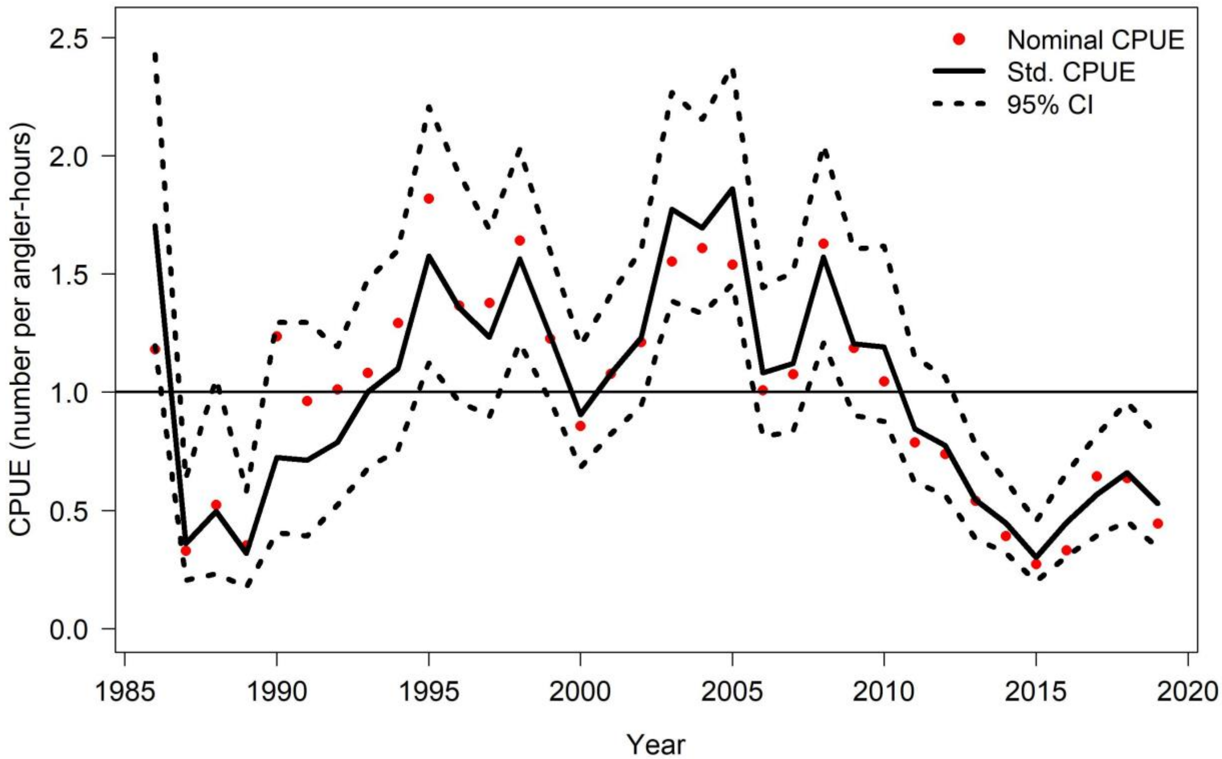

Figure 14. Standardized index with 95% confidence interval, and nominal CPUE for Gag Grouper for the Charterboat and Private combined recreational fishery. The index was scaled to the mean value of the entire time series.

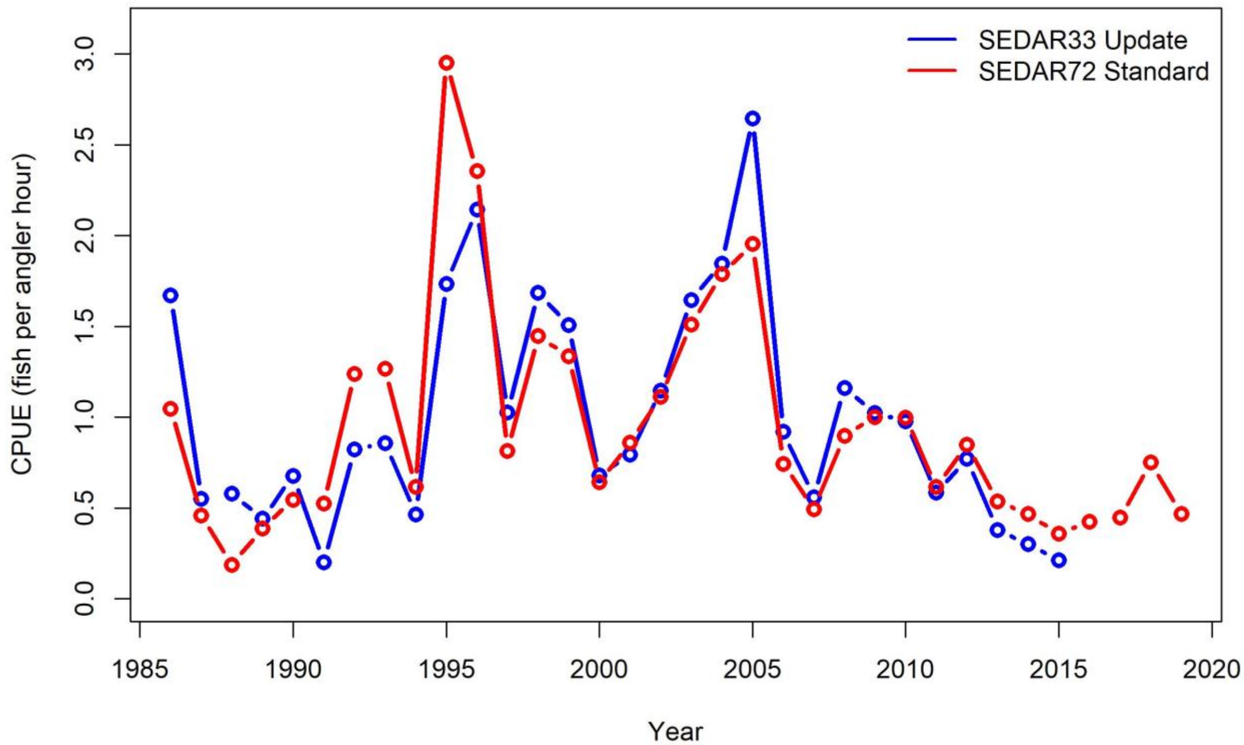

Figure 15. Standardized index for Gag Grouper from the Charterboat recreational fishery for SEDAR72 compared to the index provided during SEDAR33U. For comparison, both indices have been normalized by their respective means.

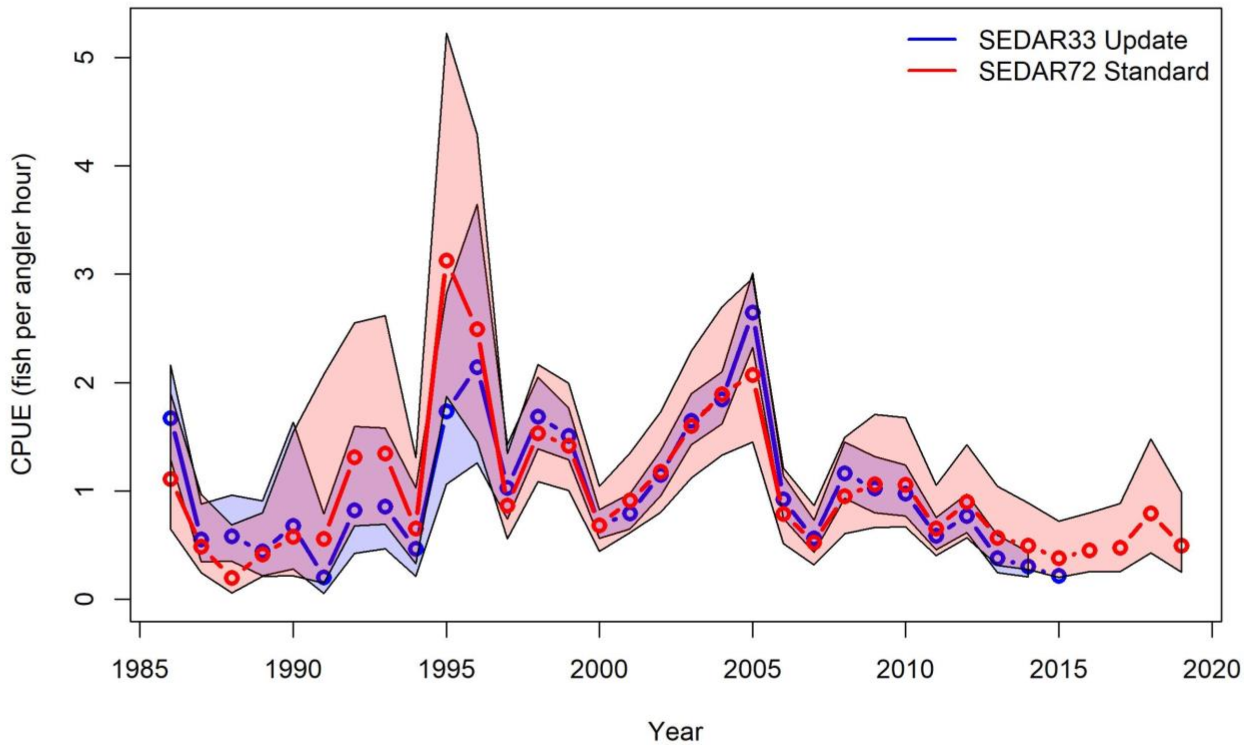

Figure 16. Comparison of index for Gag Grouper from the Charterboat recreational fishery for SEDAR72 compared to the index provided during SEDAR33U with confidence intervals.

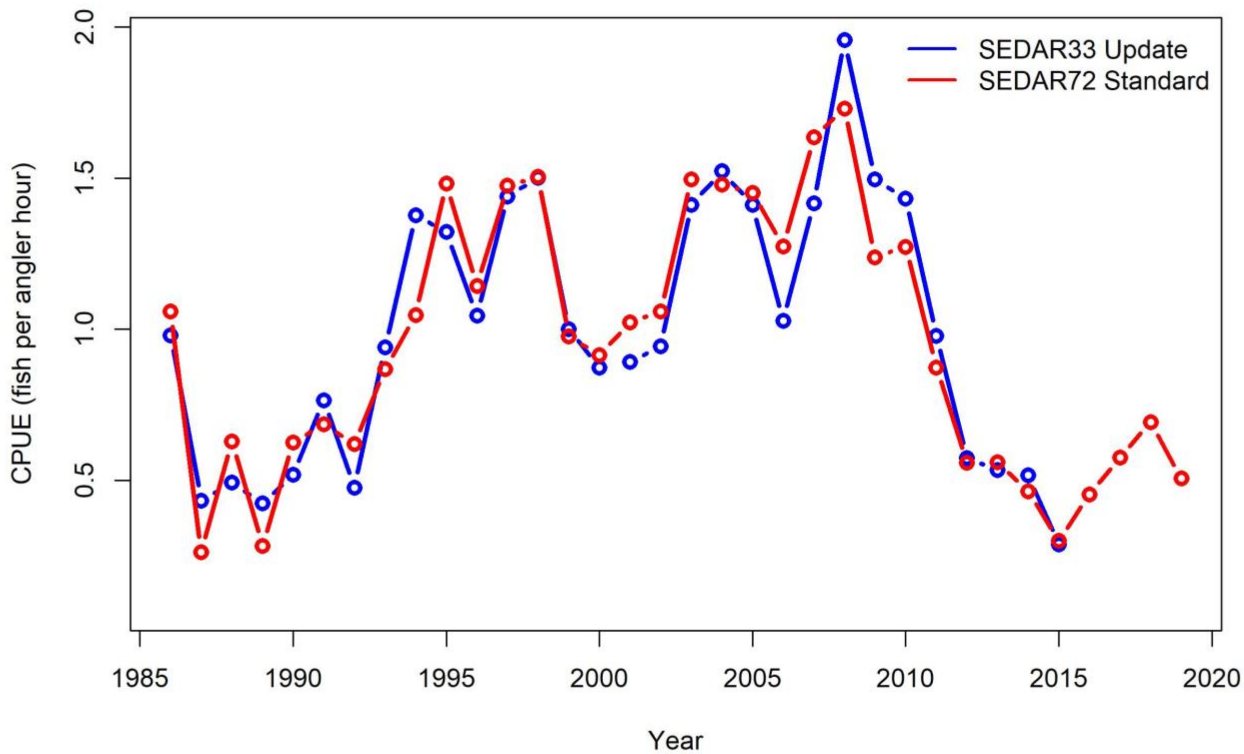

Figure 17. Standardized index for Gag Grouper from the Private recreational fishery for SEDAR72 compared to the index provided during SEDAR33U. For comparison, both indices have been normalized by their respective means.

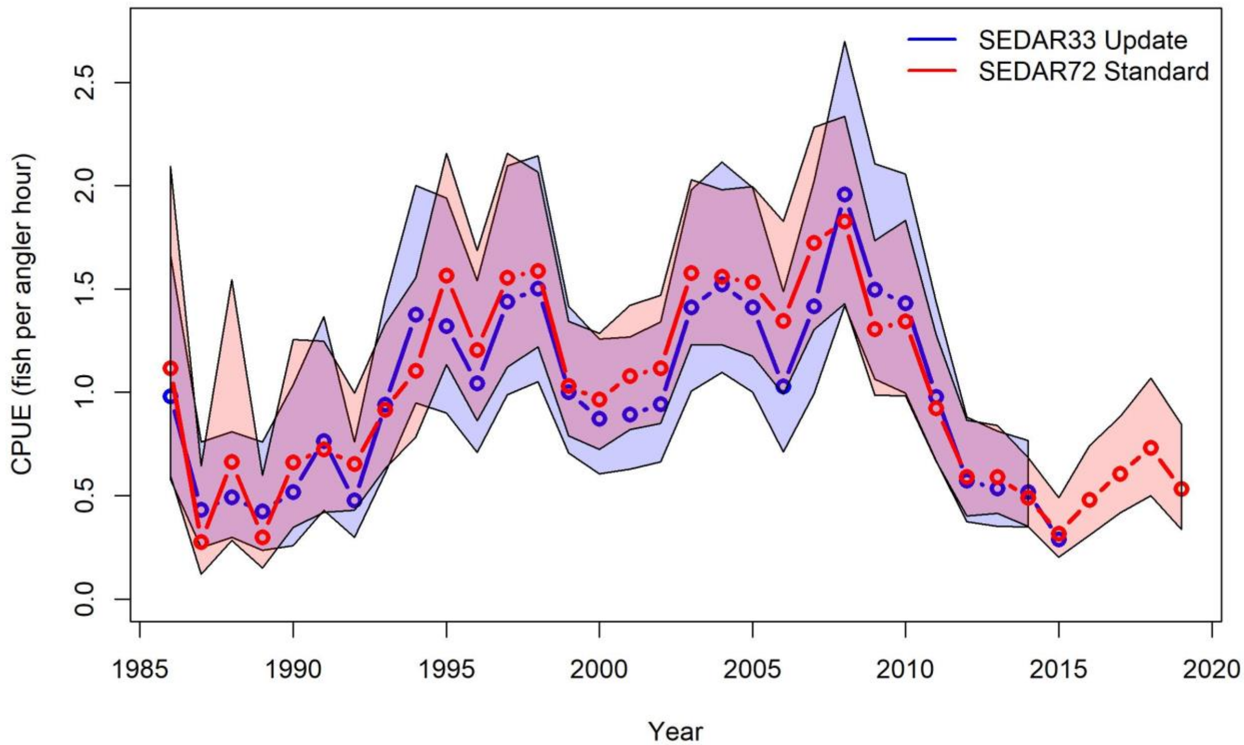

Figure 18. Comparison of index for Gag Grouper from the Private recreational fishery for SEDAR72 compared to the index provided during SEDAR33U with confidence intervals.