Standardized Catch Rates of Gray Triggerfish (*Balistes capriscus*) from the U.S. Headboat Fishery in the Gulf of Mexico, 1986-2017

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SEDAR62-WP-03

26 February 2019

Please cite this document as:

Sagarese, Skyler and Jeff Isely. 2019. Standardized Catch Rates of Gray Triggerfish (*Balistes capriscus*) from the U.S. Headboat Fishery in the Gulf of Mexico, 1986-2017. SEDAR62-WP-03. SEDAR, North Charleston, SC. 18 pp.

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Keywords: CPUE, catch, effort, recreational fisheries, gray triggerfish

1. Introduction

The recreational fishery in the Gulf of Mexico is surveyed by the Marine Recreational Fishery Statistics Survey conducted by NOAA Fisheries, the Texas Marine Sport-Harvest Monitoring Program conducted by the Texas Parks and Wildlife Department, and the Headboat Survey (HBS) conducted by NOAA Fisheries. The HBS has monitored catch and effort from party (head) boats in the Gulf of Mexico since 1986. HBS data were used to construct an index of gray triggerfish catch rates in the Gulf of Mexico following the same procedures as SEDAR43. The index was constructed using a delta-lognormal generalized linear model (GLM).

2. Materials and Methods

Headboat Survey

The Headboat Survey collects data on the catch and effort for individual headboat trips. Reported information includes landing date and location, vessel identification, the number of anglers, fishing location, trip duration and/or type (half/three-quarter/full/multi-day, day/night, morning/afternoon), and catch by species in number and weight.

HBS data were used to characterize abundance trends of gray triggerfish in the Gulf of Mexico. Catch per unit effort (CPUE) was calculated on an individual trip basis. CPUE for each trip was defined as the number of gray triggerfish landed on a trip divided by the effort, where effort was the product of the number of anglers and the total hours fished. To estimate effort for each trip type, the following assumptions were necessary:

½ day trip = 5 hours fished
¾ day trip = 7.5 hours fished
Full day trip = 10 hours fished
Multi-day trip = >10 hours fished

Data were filtered following the same steps as SEDAR43. Trips were eliminated if they had missing values for any of the key factors, were in anyway incomplete, appeared to be misreported (e.g., reported zero anglers), represented multiple entries for a single trip, or were during the closed season for gray triggerfish. Two indices (east and west Gulf of Mexico) were calculated based on geographic area (east or west of the Mississippi delta) to better represent the variance and abundance trends in each zone, because effort can vary significantly from year-to-year between the two areas.

Species Associations

An indirect method was necessary to infer targeting behavior of fishermen because no direct information was available. Following SEDAR43, the guild approach was used to select trips for use in the analysis and is based on species that frequency co-occur with gray triggerfish. The guild was defined as all fish in the NOAA Reef fish management plan (Table 1).

Standardization

A two-step delta-lognormal general linearized 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 separate GLM analyses of the proportion of trips that observed gray triggerfish and the catch rates on positive trips 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 successful trips (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.

A forward stepwise regression approach was utilized within the GENMOD procedure of SAS 9.2 (SAS Institute, 2008). In this procedure, potential 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 (i.e., 1%). Two-way interaction terms were then investigated among each of the significant factors using the same stepwise approach. Higher order interactions were not tested.

The final delta-lognormal model was fit using the factors deemed significant in the GENMOD procedure using the SAS macro GLIMMIX (SAS Institute, 2008). Factors were modeled as fixed effects except for interaction terms involving year, which were modeled as random effects. Results of the binomial (proportion positive) and lognormal (mean CPUE on successful trips) were then multiplied to attain a single index of abundance based on the year effect.

3. Results and Discussion

Species Associations

Of 249,298 trip records available in the headboat database from the Gulf of Mexico, 87,828 trips encountered gray triggerfish (West: 20,024; East: 67,804). The guild approach retained 194,024 trips for use in the index standardization (West: 47,298; East: 146,726). The proportion of positive trips before the subsetting routine was applied was 0.352 (West: 0.295; East 0.374), which increased to 0.447 after the subset was taken (West: 0.416; East: 0.457).

Western Gulf of Mexico

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

Factor	**Levels**	**Details**
Year	32	1986-2017
Season	4	Dec-Feb, Mar-May, Jun-Aug, Sep-Nov
Red Snapper Season	2	Open, Closed
Day/Night*	2	Day, Mixed
Trip Duration*	4	Half Day, Three Quarter Day, Full Day, Multi Day
Hours Fished*	9	5, 7, 10, 18, 24, 36, 48, 60, 72

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

Table 2 summarizes the standardized index, corresponding lower and upper confidence limits, coefficients of variation, and nominal CPUE. Final deviance tables are included in Table 3. The final models for the binomial and lognormal components were:

Proportion Positive = YEAR + TRIP DURATION + YEAR*TRIP DURATION
ln(CPUE) = YEAR + SEASON + RED SNAPPER SEASON + YEAR*SEASON

Note that initial model fitting attempts led to the following binomial equation: year + hours + year*hours which did not converge. Because there was only a 0.02% difference in deviance explained between hours fished and trip duration (used in SEDAR43), we reverted to the variables used during SEDAR43.

The standardized index, with 95% confidence intervals, is shown in Figure 1. All nominal values fell within the 95% confidence intervals. Relative abundance has remained consistently low since 2009, a period which reflects the lowest abundance in the entire time series (Figure 1).

Diagnostics for each component of the GLM are provided in Figures 2 and 3. The overdispersion parameter for the binomial component was 2.22. In the first half of the time series, the binomial model generally underestimates the proportion positive (Figure 2A). The proportion positive declined substantially in 2009 to below 20%. As suggested during SEDAR43, this may be associated with the forced conversion to circle hooks and implementation of the gray triggerfish rebuilding plan during this period (Smith et al. 2015). Residual analysis of the binomial model indicated no obvious patterns in the residuals by year (Figure 2B) or trip duration (Figure 2C).

The lognormal model results suggest a good fit to the data and indicated that the assumption of a lognormal distribution for positive catch was appropriate for the headboat west data (Figure 3A-B). Residual analysis of the lognormal model also indicated no obvious patterns in the residuals by year, season, or red snapper season (Figure 3C-E).

Figure 4 provides a comparison of the headboat index that resulted from the current analysis to the headboat index derived during SEDAR43 for the Western Gulf of Mexico. Although some slight differences are evident, the trend and magnitude of the continuity index are similar to the index developed during SEDAR43. In addition, all index values for SEDAR62 fall within the confidence intervals of the SEDAR43 index (Figure 5).

Eastern Gulf of Mexico

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

Factor	**Levels**	**Details**
Year	32	1986-2017
Area	3	Northwest Florida/Alabama, Florida Middle Grounds, Southwest Florida
Season	4	Dec-Feb, Mar-May, Jun-Aug, Sep-Nov
Red Snapper Season	2	Open, Closed
Day/Night*	2	Day, Mixed
Trip Duration*	4	Half Day, Three Quarter Day, Full Day, Multi Day
Hours Fished*	9	5, 7, 10, 18, 24, 36, 48, 60, 72
Vessel†	158	Individual vessels

*Only explored as factors for modeling success because these factors were confounded with effort for the CPUE response variable in the lognormal model.
†Only explored as factor for modeling success due to complications with model convergence in the binomial

Table 4 summarizes the standardized index, corresponding lower and upper confidence limits, coefficients of variation, and nominal CPUE. Final deviance tables are included in Table 5. The final models for the binomial and lognormal components were:

Proportion Positive = YEAR + AREA + YEAR*AREA
ln(CPUE) = YEAR + VESSEL + SEASON + YEAR*SEASON

Note that the year*area interaction did not fit using the updated data in the GENMOD procedure but was retained for continuity. In the lognormal model, interactions involving vessel were significant (Table 5) but were excluded from the analysis due to model convergence issues.

The standardized index, with 95% confidence intervals, is shown in Figure 6. For nearly all years (except 1986, 1991, and 2001), nominal values fell within the 95% confidence intervals. Similar to the Western Gulf, relative abundance has remained consistently low since 2009, although in the Eastern Gulf there has been a slight increase since 2014 (Figure 6).

Diagnostics for each component of the GLM are provided in Figures 7 and 8. The overdispersion parameter for the binomial component was 2.33. As observed during SEDAR43, the binomial model generally overestimates the proportion positive (Figure 7A). Residual analysis of the binomial model indicated no obvious patterns in the residuals by year (Figure 7B) or area (Figure 7C). The lognormal model results suggest a decent fit to the data and indicated that the assumption of a lognormal distribution for positive catch was appropriate for the data (Figure 8A-B). Residual analysis of the lognormal model also indicated no obvious patterns in the residuals by year or season (Figure 8C-D).

Figure 9 provides a comparison of the headboat index that resulted from the current analysis to the headboat index derived during SEDAR43 for the Eastern Gulf of Mexico. The continuity index is nearly identical to the index developed during SEDAR43 (Figure 9). As a result, all index values for SEDAR62 fall within the confidence intervals of the SEDAR43 index (Figure 10).

Comments on Adequacy for Assessment

The headboat indices presented in this working paper reflect the continuity indices of the headboat indices that were deemed adequate for use in the SEDAR43 assessment. However, we reiterate concerns raised during the SEDAR43 Data/Assessment process documented in Smith et al. (2015) such as:

- The impact of the 2008 regulatory changes. Future investigations should consider splitting the series in 2008 as more years of data become available or dealing with these changes directly in the stock assessment model by allowing time-varying catchability or fishery selectivity.
- The convergence issues caused by the Vessel terms
- The gray triggerfish bag limit enacted in 2013 may impact future catch rates and should be more carefully considered within the GLM in future assessments.

4. References

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5. Tables

Table 1. The reef fish guild, as defined by the NOAA reef fish management plan, used to subset the headboat database for SEDAR62 and SEDAR43.

Common Name	Scientific Name
Queen snapper	*Etelis oculatus*
Mutton snapper	*Lutjanus analis*
Schoolmaster	*L. apodus*
Blackfin snapper	*L. buccanella*
Red snapper	*L. campechanus*
Cubera snapper	*L. cyanopterus*
Gray snapper	*L. griseus*
Dog snapper	*L. jocu*
Mahogany snapper	*L. mahogoni*
Lane snapper	*L. synagris*
Silk snapper	*L. vivanus*
Yellowtail snapper	*Ocyurus chrysurus*
Wenchman	*Pristipomoides aquilonaris*
Vermilion snapper	*Rhomboplites aurorubens*
Rock hind	*Epinephelus adscensionis*
Speckled hind	*E. drummondhayi*
Red hind	*E. guttatus*
Goliath grouper	*E. itajara*
Red grouper	*E. morio*
Nassau grouper	*E. striatus*
Black grouper	*Mycteroperca bonaci*
Yellowmouth grouper	*M. interstitialis*
Gag grouper	*M. microlepis*
Scamp	*M. phenax*
Yellowfin grouper	*M. venenosa*
Yellowedge grouper	*Hyporthodus flavolimbatus*
Misty grouper	*H. mystacinus*
Warsaw grouper	*H. nigritus*
Snowy grouper	*H. niveatus*
Bank sea bass	*Centropristis ocyurus*
Rock sea bass	*C. philadelphica*
Greater amberjack	*Seriola dumerili*
Gray triggerfish	*Balistes capriscus*
Hogfish	*Lachnolaimus maximus*
Red porgy	*Pagrus*
Sand perch	*Diplectrum formosum*

Table 2. Numbers of total and positive trips, proportion of positive trips (PPT), relative nominal CPUE, and abundance index statistics for the headboat index in the Western Gulf of Mexico. Note that the recreational fishery was closed for all of 2017 (81 FR 80006).

YEAR	TRIPS	POSITIVE TRIPS	PPT	RELATIVE NOMINAL CPUE	RELATIVE INDEX	LOWER 95% CI	UPPER 95% CI	CV
1986	1322	547	0.414	1.0720	0.8160	0.4201	1.5848	0.3413
1987	1566	752	0.48	0.9751	0.7997	0.4215	1.5172	0.3286
1988	1739	784	0.451	1.6756	1.2110	0.6684	2.1940	0.3038
1989	1562	697	0.446	1.5976	1.4098	0.7703	2.5800	0.3092
1990	1608	802	0.499	1.7741	2.0312	1.1952	3.4517	0.2699
1991	1518	905	0.596	2.5869	3.3567	2.0962	5.3751	0.2387
1992	2217	1162	0.524	2.2430	2.5165	1.5178	4.1722	0.2569
1993	2475	1272	0.514	2.0052	2.1834	1.2844	3.7117	0.2700
1994	2801	1445	0.516	2.0875	2.0071	1.1644	3.4597	0.2774
1995	2528	1246	0.493	1.7074	1.6732	0.9728	2.8779	0.2762
1996	2261	1128	0.499	1.8703	1.8376	1.0481	3.2218	0.2864
1997	1957	855	0.437	1.3053	1.2837	0.7039	2.3410	0.3073
1998	2220	821	0.37	0.8875	0.9043	0.4827	1.6938	0.3217
1999	1199	436	0.364	0.5930	0.6491	0.3257	1.2938	0.3554
2000	1482	485	0.327	0.4917	0.3312	0.1623	0.6760	0.3684
2001	1691	585	0.346	0.6151	0.4806	0.2478	0.9321	0.3405
2002	1804	601	0.333	0.7352	0.7550	0.4119	1.3839	0.3100
2003	1650	685	0.415	0.8673	0.9582	0.5455	1.6833	0.2874
2004	1722	773	0.449	1.0436	1.1836	0.6882	2.0357	0.2762
2005	1737	869	0.5	0.9427	1.1616	0.7008	1.9253	0.2567
2006	1809	867	0.479	0.9787	0.9620	0.5725	1.6165	0.2639
2007	1871	816	0.436	1.1513	1.2522	0.7491	2.0931	0.2612
2008	753	298	0.396	1.1891	0.8239	0.4630	1.4660	0.2942
2009	1455	237	0.163	0.1167	0.0997	0.0494	0.2012	0.3624
2010	1236	152	0.123	0.0489	0.0387	0.0182	0.0824	0.3917
2011	1321	211	0.16	0.1213	0.0746	0.0369	0.1510	0.3635
2012	482	89	0.185	0.1275	0.0983	0.0435	0.2222	0.4251
2013	644	85	0.132	0.0531	0.0297	0.0116	0.0760	0.4975
2014	220	24	0.109	0.0359	0.0189	0.0054	0.0664	0.6963
2015	46	3	0.065	0.0358	0.0151	0.0018	0.1260	1.4400
2016	402	72	0.179	0.0657	0.0375	0.0139	0.1013	0.5288
2017	0	-	-	-	-	-	-	-

Table 3. Final deviance tables for the Western Gulf of Mexico gray triggerfish regressions from the headboat 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.

Binomial Model for Success (whether or not a trip landed gray triggerfish)								
Factor	**DF**	**Deviance**	**Residual Df**	**Residual Deviance**	**AIC**	**% Deviance Reduced**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	64246.6	47297	64246.6	64246.60	-	-32123.3	-
Year	31	61313.8	47267	2932.8	61313.80	4.50%	-30656.9	2932.8
Trip Duration	4	60222.6	47264	1091.2	60222.60	1.77%	-30111.3	1091.2
Year * Trip Duration	90	58991.6	47175	2322.2	58991.60	1.86%	-29495.8	1231.0
Lognormal Model for Catch Rates From Positive Trips								
Factor	**DF**	**Deviance**	**Residual Df**	**Residual Deviance**	**AIC**	**% Deviance Reduced**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	30012.0	19703	30012.0	64208.60	-	-32104.3	-
Year	31	25860.1	19673	4151.9	61274.60	13.70%	-30637.3	2934.0
Season	4	24843.4	19670	1016.7	60484.40	3.92%	-30242.2	790.2
Red Snapper Season	2	24362.2	19669	481.2	60098.80	1.93%	-30049.4	385.6
Year * Season	83	23996.3	19587	365.9	59800.80	1.09%	-29900.4	298.0

Table 4. Numbers of total and positive trips, proportion of positive trips (PPT), relative nominal CPUE, and abundance index statistics for the headboat index in the Eastern Gulf of Mexico. Note that the recreational fishery was closed for all of 2017 (81 FR 80006).

YEAR	TRIPS	POSITIVE TRIPS	PPT	RELATIVE NOMINAL CPUE	RELATIVE INDEX	LOWER 95% CI	UPPER 95% CI	CV
1986	2686	886	0.33	0.3361	0.7851	0.4556	1.3530	0.2772
1987	2562	948	0.37	0.4090	0.7044	0.3859	1.2857	0.3078
1988	4052	2071	0.511	0.8504	0.7871	0.4296	1.4421	0.3098
1989	4753	2638	0.555	1.3058	1.8592	1.2204	2.8326	0.2129
1990	8022	4292	0.535	2.2675	2.4748	1.6496	3.7127	0.2049
1991	7110	3342	0.47	1.2814	2.1039	1.4311	3.0932	0.1945
1992	7424	3927	0.529	1.7096	2.4548	1.6908	3.5640	0.1881
1993	7845	4040	0.515	1.2984	1.7904	1.1249	2.8496	0.2355
1994	7244	3238	0.447	1.3525	1.3467	0.8064	2.2490	0.2607
1995	5841	2845	0.487	1.4683	1.2951	0.7261	2.3100	0.2955
1996	5677	2782	0.49	1.3745	1.1223	0.6322	1.9921	0.2929
1997	5608	3152	0.562	1.3379	1.1783	0.6825	2.0341	0.2782
1998	4890	2851	0.583	1.2785	1.1699	0.7189	1.9037	0.2471
1999	3373	1966	0.583	1.3186	1.2067	0.7961	1.8290	0.2102
2000	4393	2210	0.503	1.0910	0.7628	0.4491	1.2956	0.2696
2001	4201	2075	0.494	1.4833	0.7578	0.4104	1.3990	0.3139
2002	4209	2147	0.51	1.8676	1.2490	0.7266	2.1470	0.2759
2003	4336	2177	0.502	1.8146	1.1822	0.6802	2.0546	0.2817
2004	4783	2210	0.462	1.3376	1.1555	0.6940	1.9239	0.2591
2005	4515	2104	0.466	1.2040	1.2928	0.8355	2.0004	0.2209
2006	3700	1761	0.476	0.7067	0.7234	0.4213	1.2421	0.2753
2007	4226	1864	0.441	0.5658	0.7987	0.4657	1.3698	0.2747
2008	5655	2477	0.438	0.5315	0.5397	0.3001	0.9707	0.2999
2009	6453	2110	0.327	0.3056	0.2522	0.1271	0.5003	0.3528
2010	4926	1360	0.276	0.3357	0.2363	0.1088	0.5132	0.4028
2011	6452	2323	0.36	0.3952	0.2808	0.1402	0.5626	0.3582
2012	2864	862	0.301	0.3279	0.2427	0.1141	0.5167	0.3916
2013	3741	1100	0.294	0.3697	0.2064	0.0846	0.5038	0.4693
2014	1813	401	0.221	0.2039	0.1363	0.0517	0.3598	0.5152
2015	438	71	0.162	0.2870	0.3507	0.1324	0.9287	0.5173
2016	2934	789	0.269	0.5844	0.5541	0.2526	1.2157	0.4085
2017	0	-	-	-	-	-	-	-

Table 5. Final deviance tables for the Eastern Gulf of Mexico gray triggerfish regressions from the headboat 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. Note that the Year*Area interaction did not fit using the updated data but was retained for continuity and Vessel interactions involving Vessel were excluded from the analysis due to model convergence issues as in SEDAR43.

Binomial Model for Success (whether or not a trip landed gray triggerfish)								
Factor	**DF**	**Deviance**	**Residual Df**	**Residual Deviance**	**AIC**	**% Deviance Reduced**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	202307.6	146725	202307.6	202307.60	-	-101153.8	-
Area	3	147046.5	146723	55261.1	147046.60	27.31%	-73523.3	55261.0
Year	31	139418.2	146693	7628.3	139418.20	5.17%	-69709.1	7628.4
Year * Area	NA	NA	NA	NA	NA	NA	NA	NA
Lognormal Model for Catch Rates From Positive Trips								
Factor	**DF**	**Deviance**	**Residual Df**	**Residual Deviance**	**AIC**	**% Deviance Reduced**	**Log likelihood**	**Likelihood Ratio Test**
Null	1	108702.2	67020	108702.2	222609.20	-	-111304.6	-
Vessel	142	66657.5	66879	42044.7	189832.80	38.55%	-94916.4	32776.4
Year	31	57268.9	66849	9388.6	179658.40	14.05%	-89829.2	10174.4
Season	4	55225.6	66846	2043.3	177223.60	3.56%	-88611.8	2434.8
Vessel * Year	1107	44707.6	65740	10518.0	163063.00	17.68%	-81531.5	14160.6
Vessel * Season	320	43467.7	65421	1239.9	161178.20	2.30%	-80589.1	1884.8
Year * Season	83	42939.2	65339	528.5	160358.20	1.09%	-80179.1	820.0

6. Figures

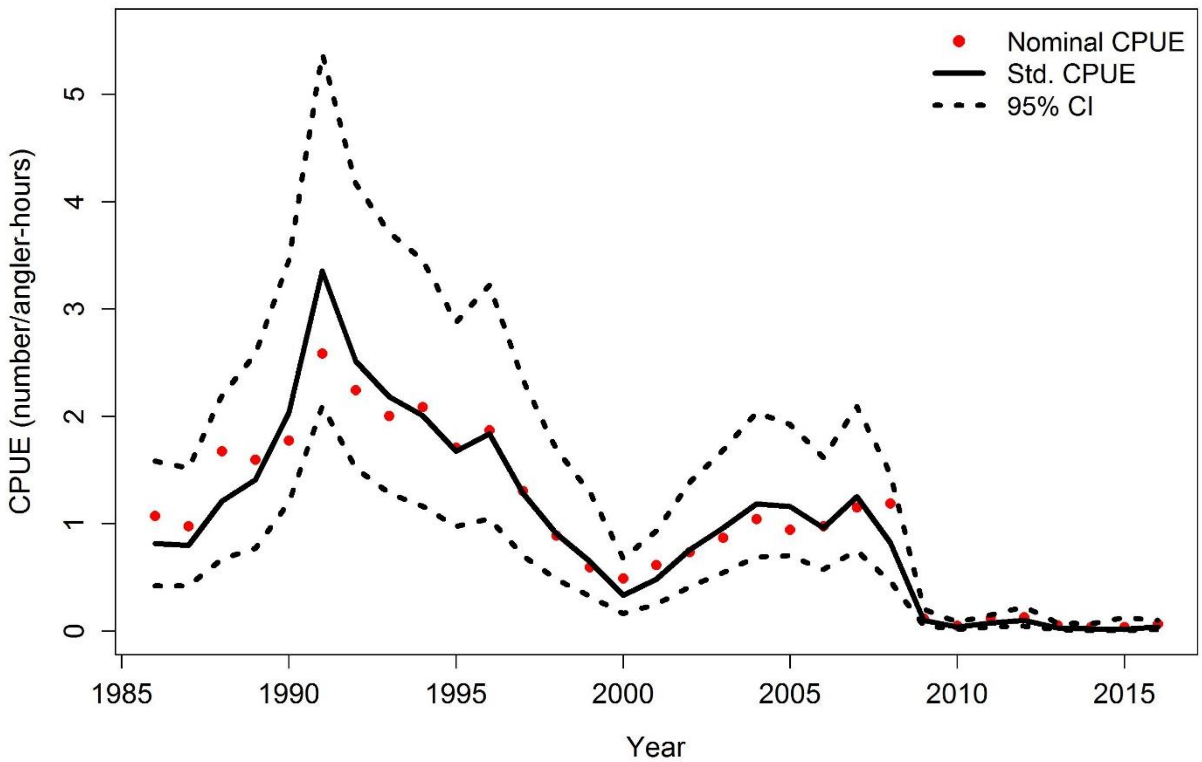

Figure 1. Standardized indices with 95% confidence intervals and nominal CPUE for the gray triggerfish headboat index for the Western Gulf of Mexico.

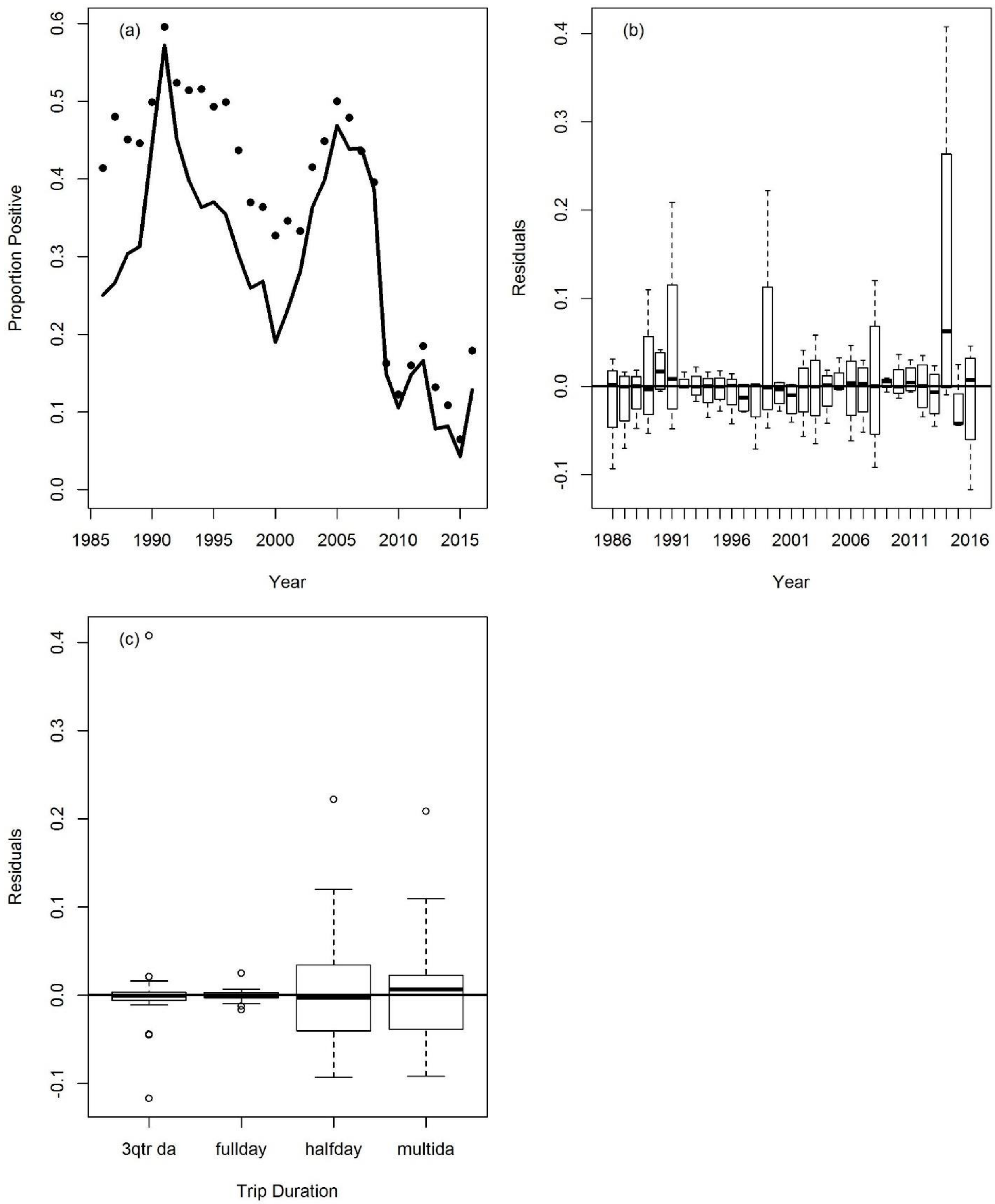

Figure 2. Diagnostic plots for the binomial model for gray triggerfish in the Western Gulf of Mexico. Shown here are the predicted (solid line) and observed proportion (dots) of positive trips by year (a), and the residuals from the binomial model by year (b), and trip duration (c).

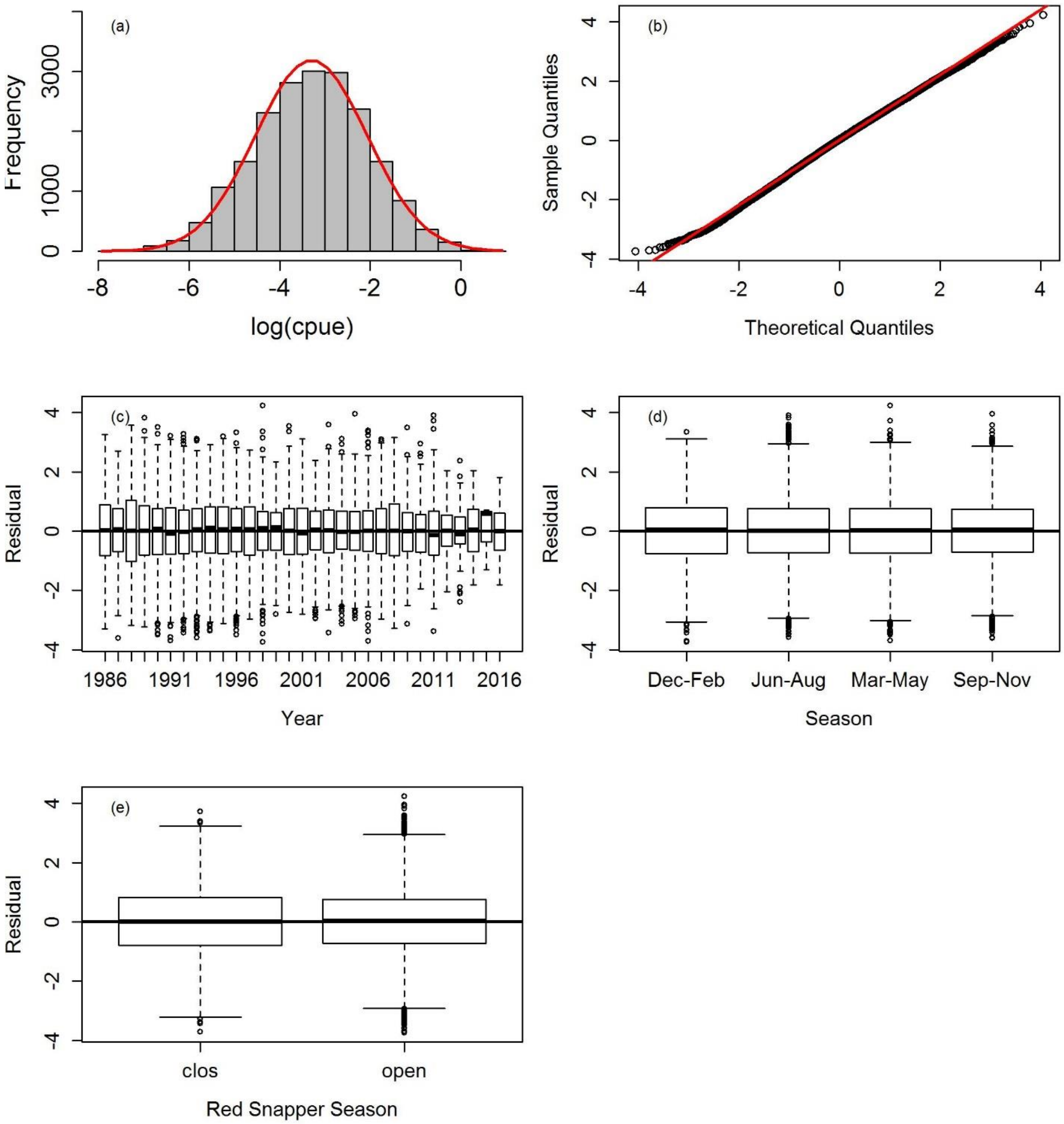

Figure 3. Diagnostic plots for the lognormal model of catch rates on positive trips for gray triggerfish in the Western Gulf of Mexico. Shown here are the frequency distribution of catch rates (a), the cumulative normalized residuals (b), and the distribution of residuals by year (c), season (d), and red snapper season (e). The red lines represent the expected normal distribution.

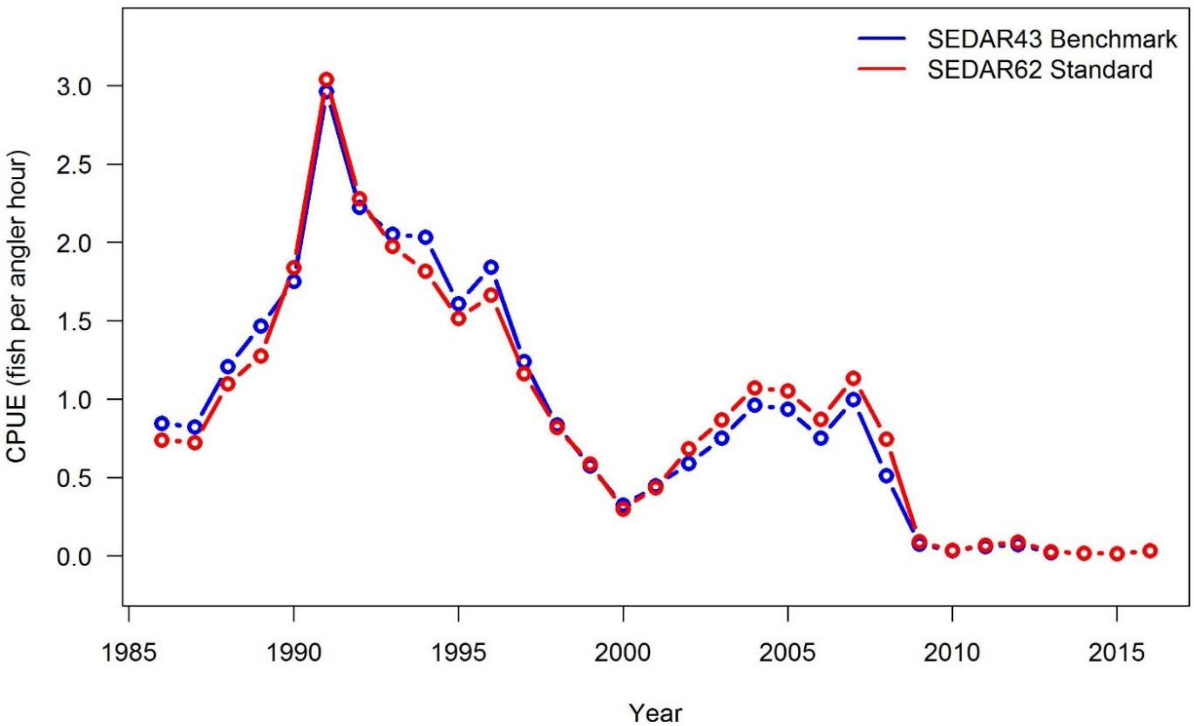

Figure 4. Standardized headboat index for gray triggerfish in the Western Gulf of Mexico for SEDAR62 compared to the headboat index provided during SEDAR43. For comparison, both indices have been normalized by their respective means.

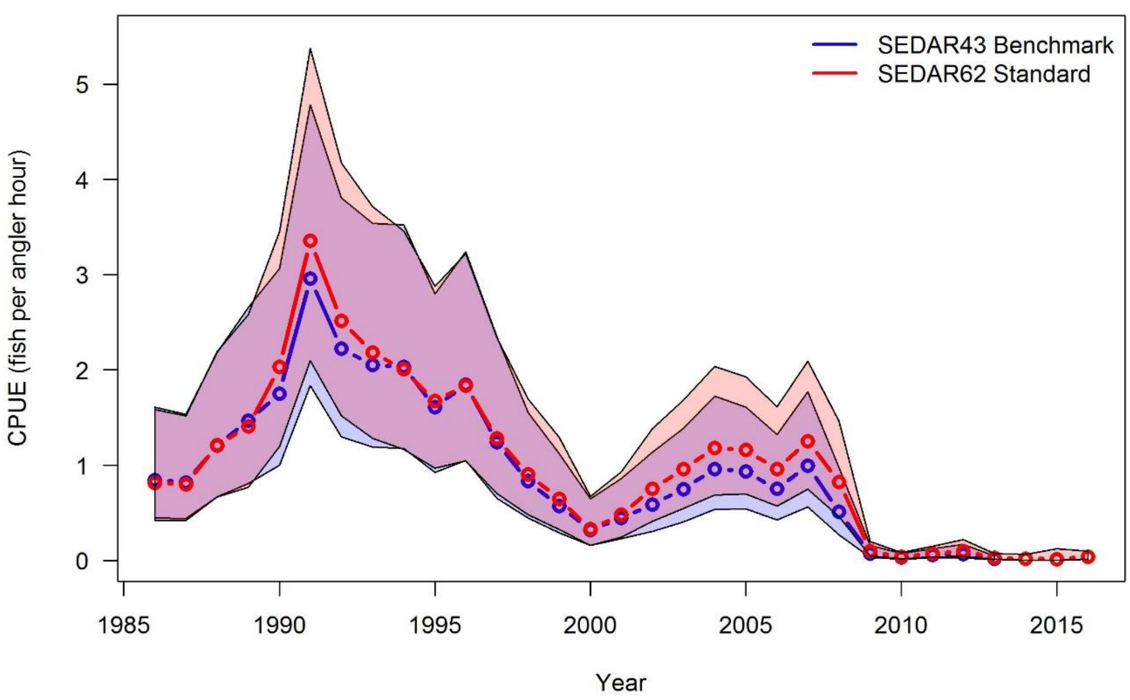

Figure 5. Comparison of headboat index for gray triggerfish in the Western Gulf of Mexico for SEDAR62 compared to the headboat index provided during SEDAR43 with confidence intervals.

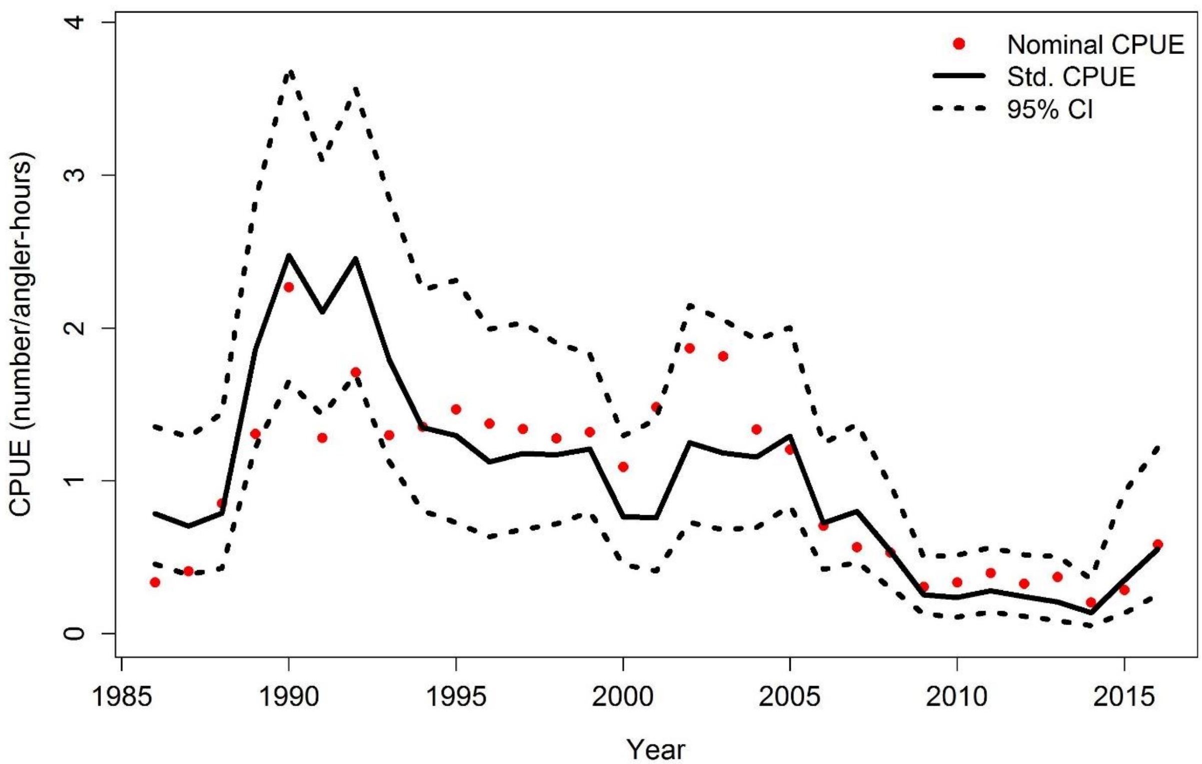

Figure 6. Standardized indices with 95% confidence intervals and nominal CPUE for the gray triggerfish headboat index for the Eastern Gulf of Mexico.

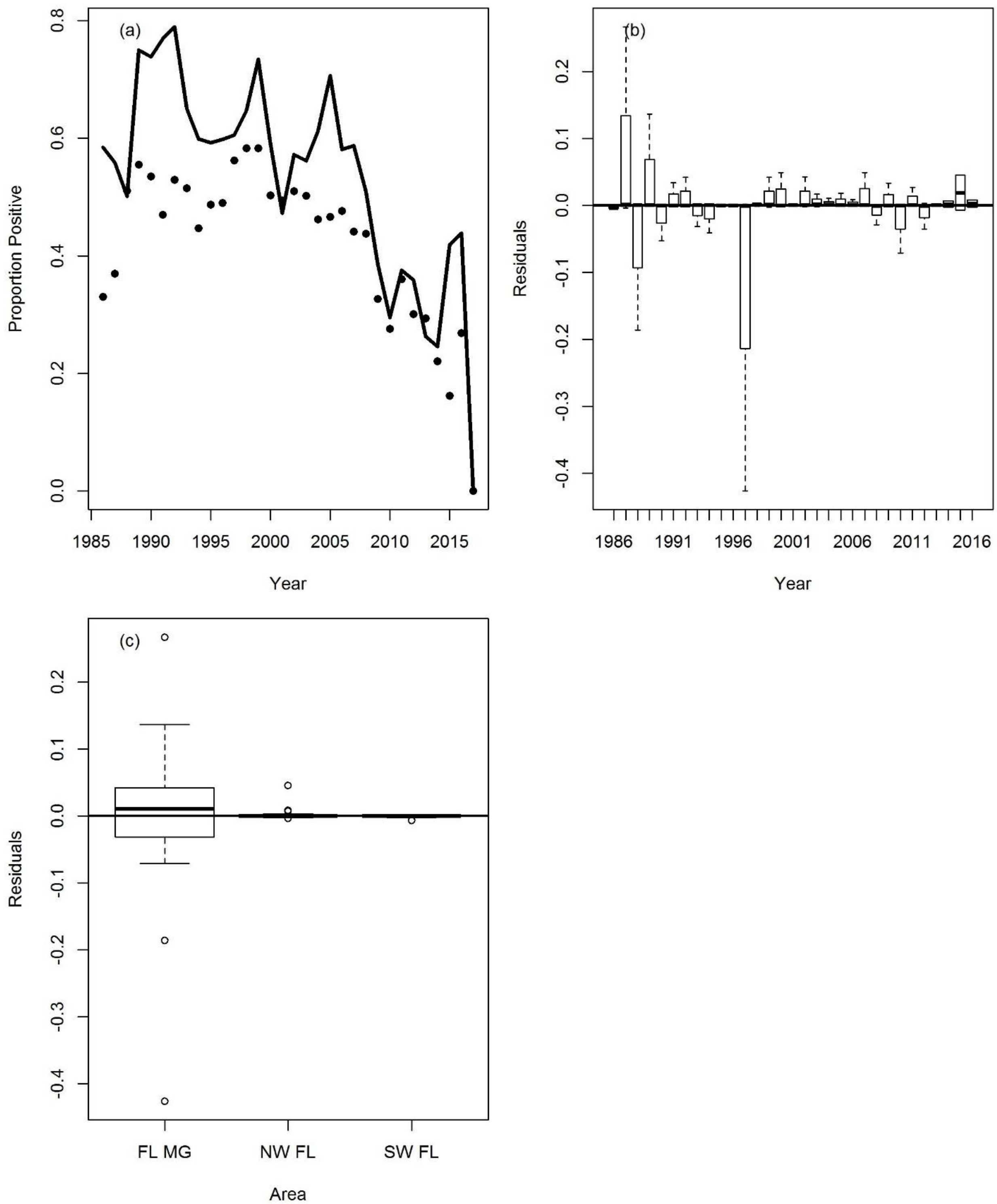

Figure 7. Diagnostic plots for the binomial model for gray triggerfish in the Eastern Gulf of Mexico. Shown here are the predicted (solid line) and observed proportion (dots) of positive trips by year (a), and the residuals from the binomial model by year (b), and area (c).

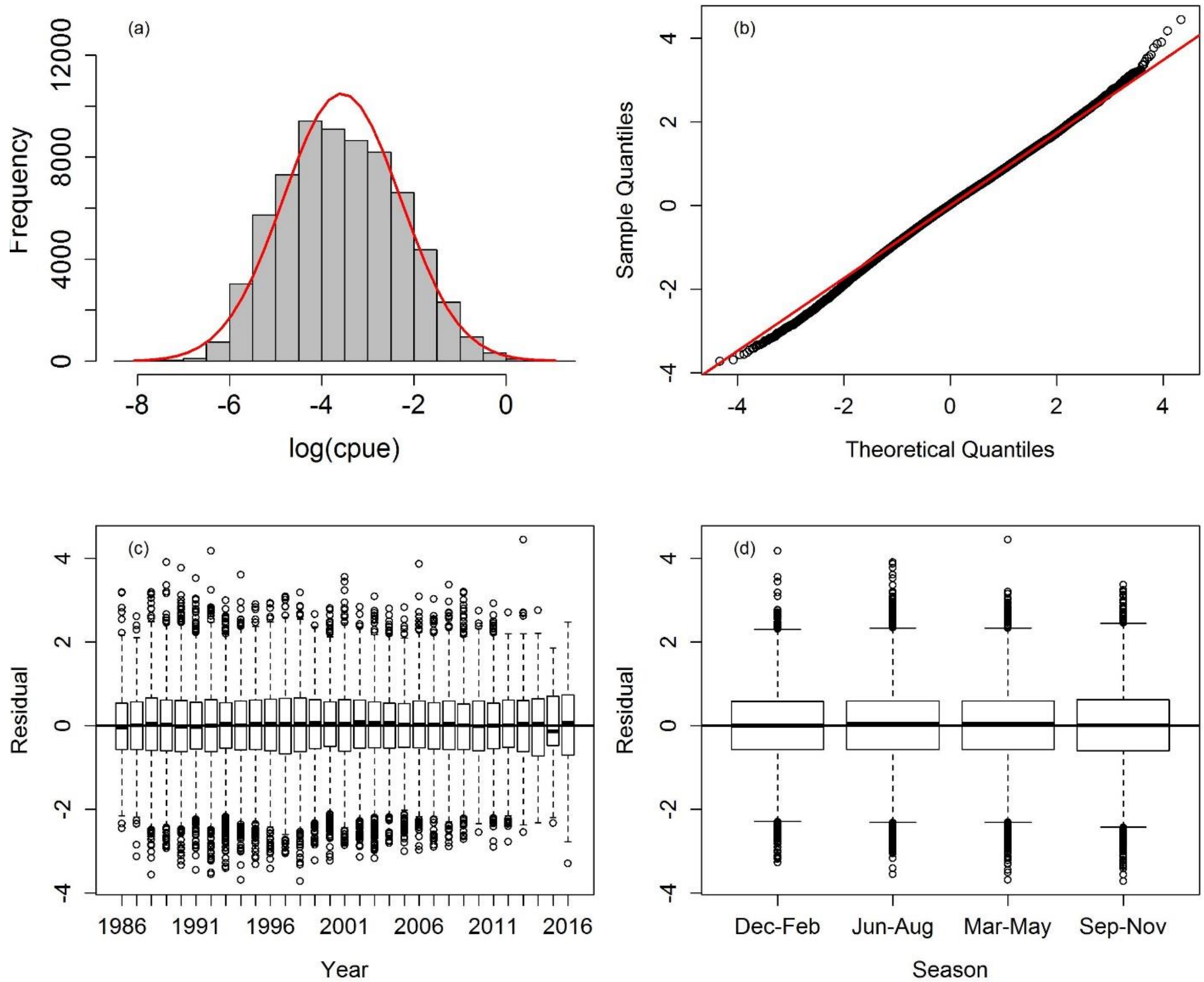

Figure 8. Diagnostic plots for the lognormal model of catch rates on positive trips for gray triggerfish in the Eastern Gulf of Mexico. Shown here are the frequency distribution of catch rates (a), the cumulative normalized residuals (b), and the distribution of residuals by year (c), and season (d). The red lines represent the expected normal distribution.

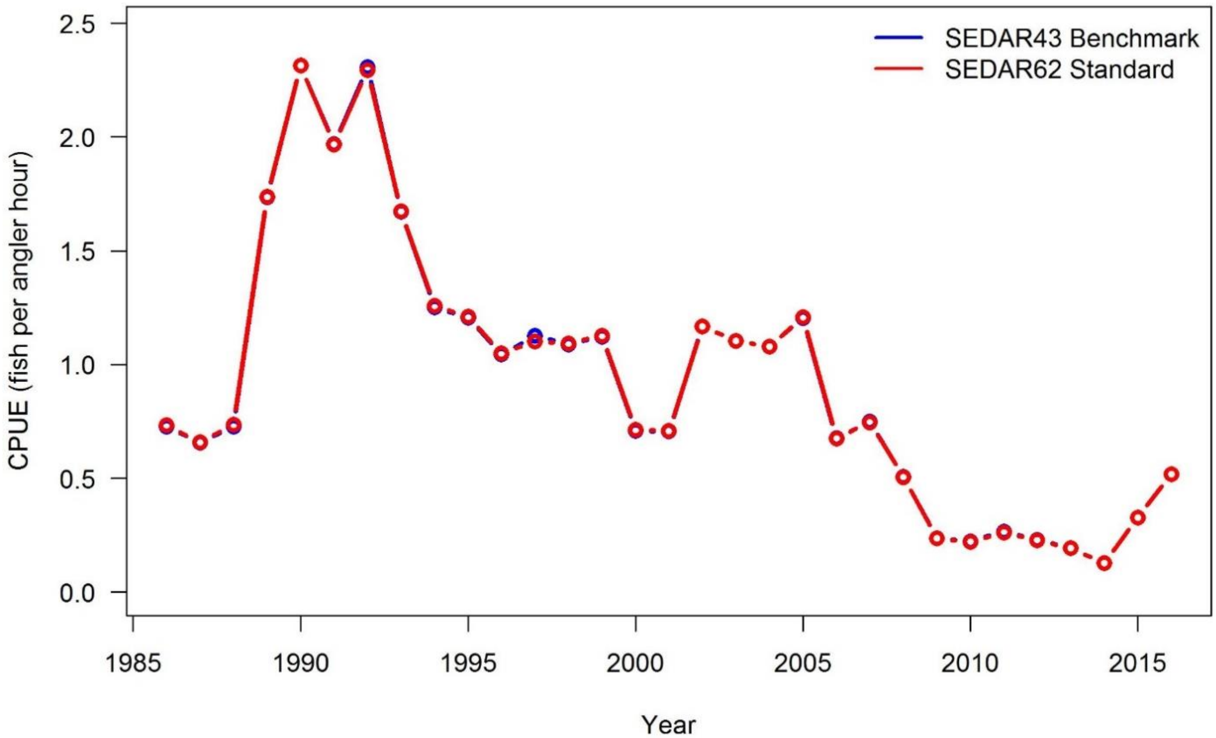

Figure 9. Standardized headboat index for gray triggerfish in the Eastern Gulf of Mexico for SEDAR62 compared to the headboat index provided during SEDAR43. For comparison, both indices have been normalized by their respective means.

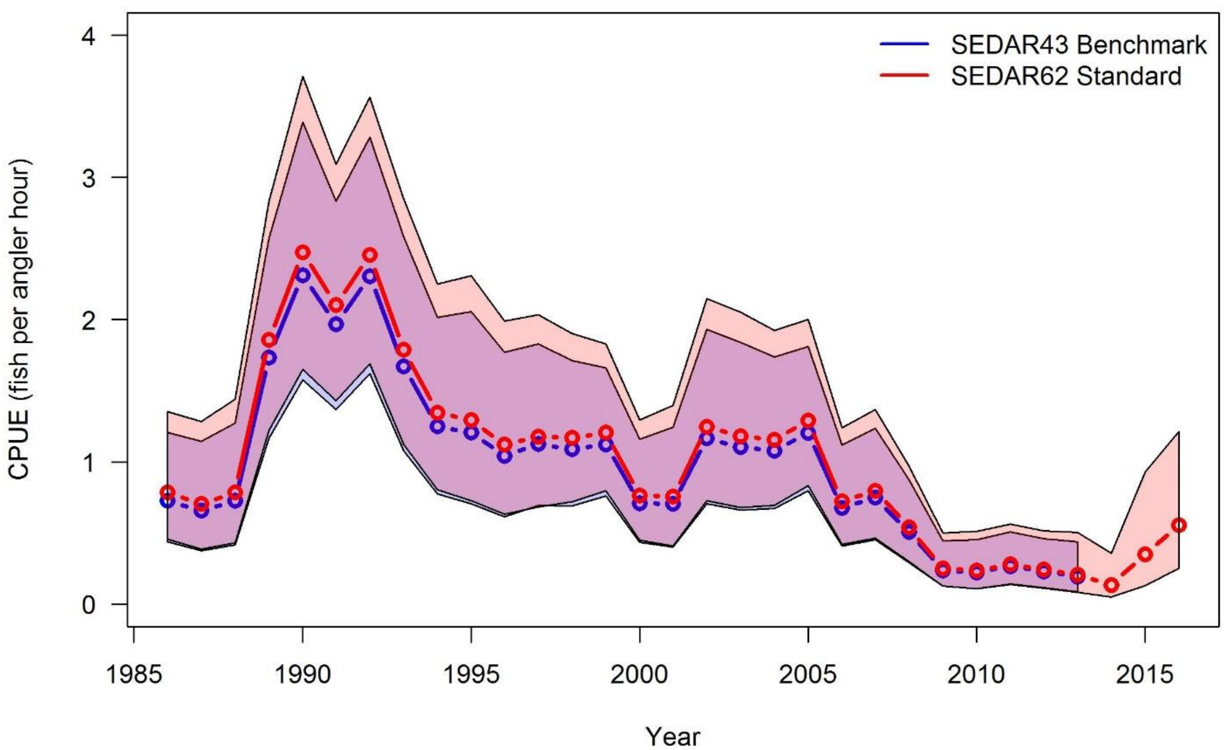

Figure 10. Comparison of headboat index for gray triggerfish in the Eastern Gulf of Mexico for SEDAR62 compared to the headboat index provided during SEDAR43 with confidence intervals.