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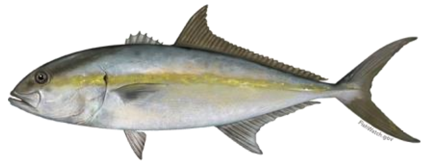
Gulf and Caribbean Branch, Sustainable Fisheries Division

SEDAR70-WP-11

2 July 2020

Please cite this document as:

Gulf and Caribbean Branch, Sustainable Fisheries Division. 2020. Standardized Catch Rate Indices for Greater Amberjack (*Seriola dumerili*) during 1990-2018 by the U.S. Gulf of Mexico Vertical Line and Longline Fisheries. SEDAR70-WP-11. SEDAR, North Charleston, SC. 34 pp.



Standardized Catch Rate Indices for Greater Amberjack (*Seriola dumerili*) during 1990-2018 by the U.S. Gulf of Mexico Vertical Line and Longline Fisheries

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June 30, 2020

Keywords

Catch, fishing effort, CPUE, abundance, commercial fisheries, handline, longline, U.S. GOM Greater Amberjack

Abstract

Standardized catch rate indices of relative abundance (Catch-per-Unit Effort; CPUE) were developed independently for the commercial handline (vertical line) and commercial longline fisheries in the U.S. Gulf of Mexico (GOM) for the SEDAR70 Operational Greater Amberjack stock assessment. Each index was developed using a delta-lognormal generalized linear model for the years 1990 to 2018 using data from the Coastal Fisheries Logbook Program. All analyses followed the same methodology used for the SEDAR33 and SEDAR33 Update stock assessments.

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 Greater Amberjack were developed for the handline and longline fleets from the U.S. GOM following the same procedures recommended during the SEDAR33 and SEDAR33 Update stock assessments.

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 fished per set.

Data from the CFLP between 1990 and 2018 were used in this study to characterize relative abundance trends of Greater Amberjack in the U.S. GOM. Catch per unit effort (CPUE) was calculated on an individual trip basis for each fleet (handline, longline). Electric reel (bandit) and manual handline were combined into a single handline 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 handline fishery, CPUE for each trip was defined as the whole weight of Greater Amberjack landed on a trip divided by the effort, where effort was the number of hook days. For the longline fishery, CPUE for each trip was defined as the whole weight of Greater Amberjack landed on a trip divided by the effort, where effort was in units of 100 hooks.

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. Trips fishing multiple gears were excluded because multiple fishing gears may be recorded for a single fishing trip. In such cases it was not possible to apportion fishing effort among the gears.

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

4. Trips that fell above or below the 99.5th percentile were considered to represent mis-reported data or data entry errors and were excluded for the following variables: trip length, number of lines for handline or number of sets for longline, number of hooks per line, number of crew, and the hours fished per day.

5. Only trips that took place exclusively in the U.S. GOM were included.

Data exclusions specific to Greater Amberjack analyses included (and followed the recommendations from the SEDAR33 Update and SEDAR33 assessments):

1. Data from Area 1 (Florida Keys and the Dry Tortugas) were excluded because these fish are considered part of the Atlantic stock of Greater Amberjack.

2. For handline gear, only trips that fished less than 10 hooks per line were included because Greater Amberjack were observed to occur in greater weights in trips with fewer hooks. As such, trips with greater than 10 hooks per line were interpreted to have only captured Greater Amberjack incidentally. In addition, handline trips that reported less than one hour fished per day were not included.

3. For longline gear, only trips that reported at least 10 sets per day or trip duration of only one day were included in the analysis.

4. Seasonal closures and regulatory closures have been employed to manage the commercial Greater Amberjack fishery. Starting in 1998, the fishery was closed from March through May for Greater Amberjack. As a result, trips that took place during these months were removed for all years in the dataset (1990 to 2018). These closed season months were also removed for years prior to 1998 because including these months in the model for only some years could bias the index due to seasonal differences in abundance of Greater Amberjack. Annual commercial fishery quotas were met between 2009 and 2016 (GMFMC 2017), leading to closures prior to the end of each calendar year. All commercial trips during closed seasons for Greater Amberjack were excluded.

5. Indices started in 1990 following the SEDAR33 Assessment Workshop Panel determination that the survey in Florida was appropriately random. To account for the change in sampling, the commercial data form Florida for the years 1990-1992 were up-weighted by 5.

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 Greater Amberjack 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 to Greater Amberjack. If effort on a trip was determined to occur in similar habitat to Greater Amberjack, then that trip was used in the analysis (Stephens and MacCall 2004). In addition, any trips that may have caught exclusively Greater Amberjack were kept in the dataset and included in the analysis following SEDAR33 recommendations.

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 trips that caught at least one Greater Amberjack (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 each lognormal model and gear, the response variable, ln(*CPUE*), was calculated as:

Handline ln(CPUE) = ln(whole pounds of Greater Amberjack)/hook days.

Longline ln(CPUE) = ln(whole pounds of Greater Amberjack)/100 hooks.

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. Two-way interactions were screened and were only retained if the model improvement was significant according to the likelihood ratio test ($p< 0.0001$). Significant YEAR*FACTOR interaction terms were modeled as random effects.

Development of Index

For each fishery, 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 (Little et al. 1996; glmm800MaOB.sas: Russ Wolfinger, SAS Institute). 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 of the entire time-series.

Results and Discussion

Index of Abundance - handline

Species Associations

The minimum difference between the predicted and the observed number of trips that reported Greater Amberjack occurred at the probability threshold of 0.19 (**Figure 2A**). Predicted trips showed a general increasing trend until the mid-2000s and declined thereafter (**Figure 2B**). Trips with a predicted probability greater than the critical threshold probability were considered as trips that targeted Greater Amberjack (**Figure 2C**). Nominal CPUE values were generally similar before and after applying the Stephens and MacCall (2004) approach, with nominal CPUE low in the first half of the time series and substantially higher after 2010 (**Figure 2D**). This method retained 10.4% of the total trips, and 38.4% of trips that reported Greater Amberjack. Prior to trip selection, there were 89,060 trips and the proportion positive was 0.12, and after selection there were 9,248 trips and the proportion positive was 0.44. **Table A1** provides the total trips after logbook filtering and SM trip selection per year.

The Stephens and MacCall (2004) trip subsetting approach identified 37 species which were captured with Greater Amberjack (**Table 1**). Warsaw Grouper, Scamp, Black Grouper, Wahoo, and Blue Runner were positively correlated to Greater Amberjack whereas Grunts, White Grunt, Unc Atlantic Black Sea Bass, Yellowtail Snapper, and Lane Snapper were negatively correlated. Trends in species composition were similar compared to the previous assessment (**Figure 3**).

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:

Name	DF	Details
Year	29	1990-2018
AREAgroup	4	FL_W_Coast (2-5), FL_BigBend (6-7), FL_PanHand (8-9), West_of_FL (10-21)
AREAgroup2	4	FL_W_Coast (2-6), FL_BigBend (7), FL_PanHand (8), West_of_FL (9-21)
AREAgroup3	6	FL_SW (2-4), FL_NW (5-6), BigBend (7), PanHand (8), N_GULF (9-13), TX_LA (14-21)
season	4	Fall, Spring, Summer, Winter
wave	6	1, 2, 3, 4, 5, 6
quarter	4	First, Fourth, Second, Third
binCREW*	4	1, 2, 3, 4+
binHRS*	9	100, 200, 300, 400, 500, 600, 700, 800, 900
binAWAY*	7	1, 2, 3, 4, 5, 6, 7+

*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

Final deviance tables are included in **Table 2**. The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive trips) components were:

$$ProportionPositive = YEAR + AREAGROUP + BINCREW + YEAR * AREAGROUP$$

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

Diagnostics for each component of the GLM are provided in **Figure 4** and **Figure 5**. The overdispersion parameter for the binomial component was 1.70. The expected proportion of positive trips was similar to the observed proportion of positive trips with the exception of the first few and last few years (**Figure 4A**). The predicted proportion positive ranged from 0.34 to 0.83, and has generally remained between 0.43 and 0.57 showing a slight increase since 2011. Residual analysis of the binomial model showed no obvious patterns in the residuals by year (**Figure 4B**), area group (**Figure 4C**) or crew (**Figure 4D**).

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 5A-B**). Residual analysis of the lognormal model showed no obvious patterns in the residuals by year before 2009 (**Figure 5C**) or area group (**Figure 5D**).

Table 3 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of trips. Nominal values generally fell within the 95% confidence intervals of the standardized index, with exceptions noted in 1990 (**Figure 6**). Relative abundance remained relatively low until 2010 and increased considerably thereafter (**Figure 6**). Relative abundance peaked in 2017, a near five-fold increase, and was lowest in 1992 (**Figure 6**).

Figure 7 provides a comparison of the SEDAR70 handline index to the indices derived for the SEDAR33 Update and SEDAR33 stock evaluations. All SEDAR70 index values fall within the confidence intervals of the SEDAR33 Update index (**Figure 8**). Overall, the relative trend and magnitude of the SEDAR70 index is generally similar to the SEDAR33 Update index.

Index of Abundance - longline

Species Associations

The minimum difference between the predicted and the observed number of trips that reported Greater Amberjack occurred at the probability threshold of 0.35 (**Figure 9A**). Observed and predicted trips were very similar over time, with a gradual increase until the mid-2000s followed by a decline (**Figure 9B**). Trips with a predicted probability greater than the critical threshold probability were considered as trips that targeted Greater Amberjack (**Figure 9C**). Nominal CPUE was generally similar both before and after applying the Stephens and MacCall (2004) approach, although some years diverged greatly (**Figure 9D**). This method retained 22.4% of the total trips, and 56.5% of trips that reported Greater Amberjack. Prior to trip selection, there were 18,018 trips and the proportion positive was 0.22, and after selection there were 4,031 trips and the proportion positive was 0.56. **Table A2** provides the total trips after logbook filtering and SM trip selection per year.

The Stephens and MacCall (2004) trip subsetting approach identified 55 species which were captured with Greater Amberjack (**Table 4**). Mutton Snapper, Yellowedge Grouper, Unclassified Tilefish, Barracuda, and Whitebone Porgy were positively correlated to Greater Amberjack whereas Lesser Amberjack, Tiger Shark, Blacktip Shark, Almaco Jack, and Bull Shark were negatively correlated. Trends in species compositions were generally similar compared to the previous assessment (**Figure 10**).

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:

Name	DF	Details
Year	29	1990-2018
Month	12	Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec
AREAgroup	5	FL_SW (2-3), FL_C (4-5), FL_BigBend_MS (6-11), LA (12-16), TX (17-21)
AREAgroup2	2	FL (2-7), PanHand_TX (8-21)
AREAgroup3	3	SW_FL (2-4), WFL_BigBend (5-7), PanHand_TX (8-21)
season	4	Fall, Spring, Summer, Winter
wave	6	1, 2, 3, 4, 5, 6
quarter	4	First, Fourth, Second, Third
CREW*	6	1, 2, 3, 4, 5, 6
AWAY*	20	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20
binCREW*	3	2, 3, 4+
binHRS*	3	200, 400, 500
binAWAY*	4	5, 10, 15, 20

*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

Final deviance tables are included in **Table 5**. The final models for the binomial (i.e., proportion positive) and lognormal (catch rate of positive trips) components were:

$$ProportionPositive = YEAR + AREAGROUP3 + BINAWAY + YEAR * AREAGROUP3$$

$$ln(CPUE) = YEAR + AREAGROUP3 + YEAR * AREAGROUP3$$

Diagnostics for each component of the GLM are provided in **Figure 11** and **Figure 12**. The overdispersion parameter for the binomial component was 1.12. The expected proportion of positive trips was similar to the observed proportion of positive trips with the exception of the last few years where trips were underestimated (**Figure 11A**). The expected proportion positive ranged from 0.3 to 0.72, and has generally remained between 0.45 and 0.61. A significant decline in the proportion of positive trips is indicated since about 2005. Residual analysis of the binomial model showed no obvious patterns in the residuals by year (**Figure 11B**), area group 3 (**Figure 11C**), or days away (**Figure 11D**).

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 12A-B**). Residual analysis of the lognormal model also showed no obvious patterns in the residuals by year (**Figure 12C**) or area group 3 (**Figure 12D**).

Table 6 summarizes the standardized index, corresponding lower and upper 95% confidence limits, annual coefficients of variation, nominal CPUE, and number of trips. Nominal values generally fell within the 95% confidence intervals, with exceptions noted in 1994, 1996, 1998 and 2006 (**Figure 13**). Relative abundance has remained fairly stable with some oscillations throughout the time series, with peak abundance in 2009 and the lowest value in 1994 (**Figure 13**).

Figure 14 provides a comparison of the SEDAR70 longline index to the indices derived for the SEDAR33 Update and SEDAR33 stock evaluations. A fair number of SEDAR70 index values fall outside the confidence intervals of the SEDAR33 Update index, including the 2011, 2012, 2013 and 2015 estimates (**Figure 15**). For the remaining years, the relative trend and magnitude of the SEDAR70 index were generally similar to the SEDAR33 Update index.

Comments on Adequacy for Assessment

The commercial indices presented in this working paper reflect the continuity indices developed following the methods of the SEDAR33 and SEDAR33 Update stock assessments. In the SEDAR33 Benchmark assessment, the decision was made to truncate the commercial CPUE indices in 2010 in order to avoid including years with vastly shortened seasons and potentially different targeting behavior despite a 2012 terminal year. While split indices were considered during the SEDAR33 Update assessment, the entire time series was utilized (1990-2015), with similar pitfalls of using data from years where fishing season was shortened due to management regulations. Given the rapid changes in the indices seen since 2010, particularly for the handline fishery, it may not be appropriate to use the full commercial CPUE time series.

Further research is warranted to investigate the potential for including a new GLM factor that accounts for the management regulations, which have resulted in the shortened Greater Amberjack fishing seasons. However, given the complexities of current management regimes in the U.S. GOM, it may not be feasible to effectively standardize commercial CPUE.

References

Gulf of Mexico Fishery Management Council (GMFMC). 2017. Final Framework Action to the Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico Including Environmental Assessment, Regulatory Impact Review, and Regulatory Flexibility Act Analysis. 127 pp.

Hinton, Michael G. and M.N. Maunder. 2004. Methods for standardizing CPUE and how to select among them. Col. Vol. Sci. Pap. ICCAT 56(1): 169-177.

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

Lo, N.C., L.D. Jacobson and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-2526.

Maunder, M.N. and A.E. Punt. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70: 141-159.

SAS Institute Inc. 1997, SAS/STAT Software: Changes and Enhancements through Release 6.12. Cary, NC:Sas Institute Inc., 1997. 1167 pp.

Stephens, A., and A. MacCall. 2004. A multispecies approach to subsetting logbook data for purposes of estimating CPUE. Fish. Res. 70:299-310.

Tables

Table 1. Association coefficients of other species with Greater Amberjack in at least 1% of handline trips in the U.S. GOM. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
1.033	Warsaw Grouper	*Epinephelus nigritus*
0.968	Scamp	*Mycteroperca phenax*
0.778	Black Grouper	*Mycteroperca bonaci*
0.759	Wahoo	*Acanthocybium solandri*
0.708	Blue Runner	*Caranx crysos*
0.669	Vermilion Snapper	*Rhomboplites aurorubens*
0.622	Mutton Snapper	*Lutjanus analis*
0.539	Almaco Jack	*Seriola rivoliana*
0.516	Cobia	*Rachycentron canadum*
0.503	Triggerfishes	*Balistidae*
0.475	Yellowedge Grouper	*Epinephelus flavolimbatus*
0.435	Dolphinfish	*Coryphaena*
0.327	Gag Grouper	*Mycteroperca microlepis*
0.312	Snowy Grouper	*Epinephelus niveatus*
0.255	Mangrove Snapper (dup Of 3760)	*Lutjanus griseus*
0.249	Blueline Tilefish	*Caulolatilus microps*
0.232	Gray Triggerfish	*Balistes capriscus*
0.184	Hogfish	*Lachnolaimus maximus*
0.152	Little (tunny) Tuna	*Euthynnus alletteratus*
-0.044	Unc Red Porgy	*Pagrus pagrus*
-0.047	Whitebone Porgy	*Calamus leucosteus*
-0.052	Lesser Amberjack	*Seriola fasciata*
-0.062	Jolthead Porgy	*Calamus bajonado*
-0.088	White Sea Trout	*Cynoscion arenarius*
-0.217	Knobbed Porgy	*Calamus nodosus*
-0.319	King Mackerel	*Scomberomorus cavalla*
-0.331	Speckled Hind	*Epinephelus drummondhayi*
-0.364	Margate	*Haemulon album*
-0.433	Red Grouper	*Epinephelus morio*
-0.502	Spanish Mackerel	*Scomberomorus maculatus*
-0.616	Bluestriped Grunt	*Haemulon sciurus*

Table 1 Continued. Association coefficients of other species with Greater Amberjack in at least 1% of handline trips in the U.S. GOM. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
-0.636	Red Snapper	*Lutjanus campechanus*
-0.646	Lane Snapper	*Lutjanus synagris*
-0.695	Yellowtail Snapper	*Ocyurus chrysurus*
-0.700	Unc Atlantic Black Sea Bass	*Centropristis striata*
-0.730	White Grunt	*Haemulon plumieri*
-0.763	Grunts	*Haemulidae*

Table 2. Deviance tables for the regression models for Greater Amberjack in the U.S. GOM for the handline index. 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 variable in red was included to force the year effect in the standardization process.

Factor	DF	Deviance	Residual DF	Residual Deviance	AIC	Deviance Reduced	Log likelihood	Likelihood Ratio Test
Binomial								
Null	1	12698	9247	12698	12698	-	-6349	-
AREAgroup	4	12237	9244	461	12237	3.60	-6118	461
binCREW	4	11900	9241	336	11900	2.72	-5950	336.6
Year	29	11717	9213	183	11717	1.24	-5858	183.6
Year*AREA group	85	11402	9129	314	11402	1.79	-5701	314.2
Lognormal								
Null	1	22243	4092	22243	18544	-	-9272	-
Year	29	18586	4064	3657	17808	15.87	-8904	735.4
AREAgroup	4	17696	4061	889	17608	4.71	-8804	200.6
Year*AREA group	85	15847	3977	1849	17156	8.56	-8578	451.6

Table 3. Numbers (N) of total and positive trips, proportion of positive trips (PPT), relative nominal CPUE, and standardized abundance index statistics for Greater Amberjack in the U.S. GOM for the handline.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1990	181	39	0.215	0.046	0.171	0.047	0.625	0.723
1991	181	76	0.420	0.110	0.232	0.073	0.736	0.629
1992	290	85	0.293	0.183	0.171	0.049	0.591	0.686
1993	511	196	0.384	0.115	0.200	0.065	0.615	0.610
1994	514	218	0.424	0.145	0.230	0.075	0.705	0.608
1995	627	253	0.404	0.086	0.222	0.072	0.688	0.613
1996	646	280	0.433	0.195	0.294	0.097	0.892	0.601
1997	709	307	0.433	0.163	0.242	0.080	0.735	0.601
1998	538	222	0.413	0.206	0.247	0.080	0.762	0.610
1999	499	232	0.465	0.432	0.240	0.079	0.734	0.605
2000	400	177	0.443	0.327	0.273	0.088	0.848	0.615
2001	503	198	0.394	0.243	0.248	0.079	0.779	0.623
2002	612	235	0.384	0.298	0.296	0.095	0.925	0.619
2003	554	277	0.500	0.437	0.549	0.183	1.647	0.594
2004	442	206	0.466	0.556	0.474	0.155	1.447	0.605
2005	435	190	0.437	0.330	0.290	0.094	0.894	0.610
2006	346	186	0.538	0.356	0.348	0.115	1.052	0.598
2007	194	92	0.474	0.165	0.225	0.070	0.725	0.639
2008	203	92	0.453	0.436	0.248	0.076	0.813	0.650
2009	138	54	0.391	0.235	0.209	0.058	0.761	0.718
2010	83	38	0.458	0.500	0.553	0.151	2.026	0.723
2011	71	51	0.718	4.525	2.349	0.635	8.694	0.731
2012	46	25	0.543	2.623	3.874	0.931	16.125	0.814
2013	83	54	0.651	4.365	1.866	0.531	6.556	0.696
2014	103	64	0.621	2.253	1.883	0.534	6.633	0.698
2015	88	64	0.727	2.558	3.096	0.931	10.295	0.659
2016	102	62	0.608	1.610	1.152	0.319	4.165	0.715
2017	89	77	0.865	2.821	5.489	1.751	17.210	0.621
2018	60	43	0.717	2.680	3.328	0.916	12.089	0.718

Table 4. Association coefficients of other species with Greater Amberjack in at least 1% of longline trips in the U.S. GOM. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
0.957	Mutton Snapper	*Lutjanus analis*
0.779	Yellowedge Grouper	*Epinephelus flavolimbatus*
0.747	Unclassified Tilefish	*Malacanthidae*
0.702	Barracuda	*Sphyraenidae*
0.693	Whitebone Porgy	*Calamus leucosteus*
0.676	Warsaw Grouper	*Epinephelus nigritus*
0.628	Queen Snapper	*Etelis oculatus*
0.608	Red & White Atlantic Hake	*Urophycis*
0.540	Snowy Grouper	*Epinephelus niveatus*
0.480	Unc Red Porgy	*Pagrus pagrus*
0.465	Unc Snappers	*Lutjanidae*
0.444	Tilefish	*Lopholatilus chamaeleonticeps*
0.429	Grunts	*Haemulidae*
0.424	King Mackerel	*Scomberomorus cavalla*
0.422	Jolthead Porgy	*Calamus bajonado*
0.419	Cobia	*Rachycentron canadum*
0.413	Blueline Tilefish	*Caulolatilus microps*
0.411	Margate	*Haemulon album*
0.396	Black Grouper	*Mycteroperca bonaci*
0.380	Bearded Brotula	*Brotula barbata*
0.346	Lemon Shark	*Negaprion brevirostris*
0.309	Unc Shark Fins	*Squaliformes*
0.280	Silk Snapper	*Lutjanus vivanus*
0.270	Gag Grouper	*Mycteroperca microlepis*
0.239	Wahoo	*Acanthocybium solandri*
0.232	Unc Finfishes For Food	*Osteichthyes*
0.231	Blackfin Snapper	*Lutjanus buccanella*
0.231	Scorpionfish-thornyheads	*Scorpaenidae*
0.224	Scamp	*Mycteroperca phenax*
0.206	Vermilion Snapper	*Rhomboplites aurorubens*
0.185	Yellowfin Grouper	*Mycteroperca venenosa*

Table 4 Continued. Association coefficients of other species with Greater Amberjack in at least 1% of longline trips in the U.S. GOM. Positive numbers indicate a positive correlation.

Coefficient	Common Name	Scientific Name
0.181	Gray Triggerfish	*Balistes capriscus*
0.174	Dolphinfish	*Coryphaena*
0.169	Rock Hind	*Epinephelus adscensionis*
0.113	Cusk Eels	*Ophidiidae*
0.107	Mangrove Snapper (dup Of 3760)	*Lutjanus griseus*
0.062	Red Snapper	*Lutjanus campechanus*
0.059	Groupers	*Serranidae*
-0.001	Unc Mako Shark	*Isurus*
-0.001	Speckled Hind	*Epinephelus drummondhayi*
-0.005	Blackfin Tuna	*Thunnus atlanticus*
-0.139	Lane Snapper	*Lutjanus synagris*
-0.164	Sandbar Shark	*Carcharhinus plumbeus*
-0.208	Blacknose Shark	*Carcharhinus acronotus*
-0.248	Atlantic Sharpnose Shark	*Rhizoprionodon terraenovae*
-0.281	Yellowtail Snapper	*Ocyurus chrysurus*
-0.291	Red Grouper	*Epinephelus morio*
-0.297	Hammerhead Shark	*Sphyrnidae*
-0.301	Unc Shark	*Chondrichthyes*
-0.308	Misty Grouper	*Epinephelus mystacinus*
-0.799	Bull Shark	*Carcharhinus leucas*
-0.800	Almaco Jack	*Seriola rivoliana*
-1.194	Blacktip Shark	*Carcharhinus limbatus*
-1.198	Tiger Shark	*Galeocerdo cuvier*
-1.913	Lesser Amberjack	*Seriola fasciata*

Table 5. Deviance tables for the regression models for Greater Amberjack in the U.S. GOM for the longline index. 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 variable in red was included to force the year effect in the standardization process.

Factor	DF	Deviance	Residual DF	Residual Deviance	AIC	Deviance Reduced	Log likelihood	Likelihood Ratio Test
Binomial								
Null	1	5536.2	4030	5536.2	5536.2	-	-2768.1	-
Year	29	5399.0	4002	137.2	5399.0	1.80	-2699.5	137.2
AREAgroup3	3	5337.2	4000	61.8	5337.2	1.10	-2668.6	61.8
binAWAY	4	5278.2	3997	258.0	5278.2	3.87	-2639.1	258
Year*AREA group3	57	5165.3	3941	233.7	5165.2	2.85	-2582.6	233.8
Lognormal								
Null	1	3792.4	2243	3792.4	7545.8	-	-3772.9	-
Year	29	3523.0	2215	269.4	7380.4	5.93	-3690.2	165.4
AREAgroup3	3	3367.9	2213	155.1	7279.4	4.32	-3639.7	101
Year*AREA group3	56	3145.5	2158	222.4	7126.0	4.22	-3563.0	153.4

Table 6. Numbers (N) of total trips, relative nominal CPUE, and standardized abundance index statistics for Greater Amberjack in the U.S. GOM for the longline.

Year	N	Positive N	PPT	Relative Nominal CPUE	Relative Index	Lower 95% CI	Upper 95% CI	CV
1990	59	27	0.458	0.774	0.531	0.241	1.166	0.409
1991	88	53	0.602	1.007	0.791	0.435	1.438	0.306
1992	66	42	0.636	1.751	1.438	0.767	2.698	0.322
1993	162	86	0.531	0.861	0.563	0.328	0.968	0.275
1994	227	116	0.511	1.115	0.373	0.219	0.634	0.270
1995	233	123	0.528	0.994	0.582	0.340	0.996	0.274
1996	134	64	0.478	1.919	0.524	0.292	0.940	0.298
1997	290	140	0.483	0.518	0.587	0.348	0.989	0.266
1998	226	104	0.460	3.012	0.586	0.343	1.000	0.272
1999	224	115	0.513	0.606	0.574	0.339	0.970	0.268
2000	228	106	0.465	0.435	0.601	0.351	1.028	0.273
2001	204	117	0.574	0.490	0.731	0.438	1.222	0.261
2002	183	116	0.634	0.606	1.003	0.603	1.668	0.258
2003	276	184	0.667	0.742	1.060	0.654	1.719	0.245
2004	188	116	0.617	0.874	1.342	0.808	2.228	0.258
2005	180	124	0.689	1.192	1.817	1.105	2.986	0.252
2006	182	123	0.676	0.687	1.319	0.800	2.175	0.254
2007	143	89	0.622	0.825	0.974	0.573	1.654	0.270
2008	169	116	0.686	1.021	1.470	0.887	2.436	0.257
2009	98	72	0.735	1.483	2.044	1.204	3.471	0.269
2010	59	29	0.492	0.942	1.825	0.911	3.655	0.358
2011	47	22	0.468	0.475	0.830	0.402	1.714	0.375
2012	22	7	0.318	1.738	1.426	0.493	4.127	0.571
2013	25	10	0.400	1.062	1.912	0.745	4.905	0.498
2014	77	30	0.390	0.463	0.455	0.228	0.909	0.357
2015	61	32	0.525	1.353	1.192	0.615	2.310	0.340
2016	85	42	0.494	0.710	1.100	0.591	2.049	0.319
2017	61	26	0.426	0.792	0.750	0.366	1.536	0.370
2018	34	13	0.382	0.552	0.603	0.246	1.476	0.471

Figures

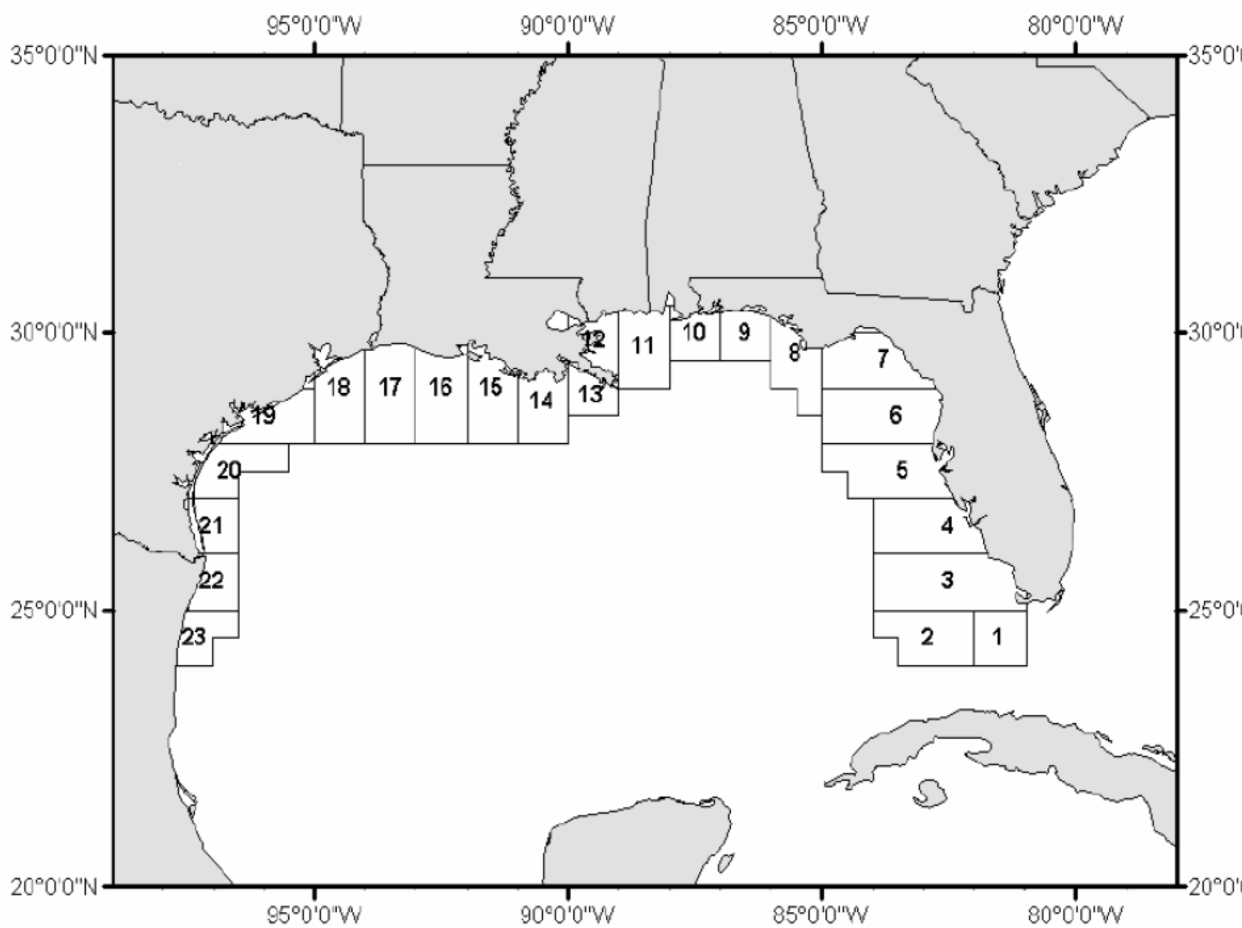

Figure 1. National Marine Fisheries Service statistical shrimp reporting grids.

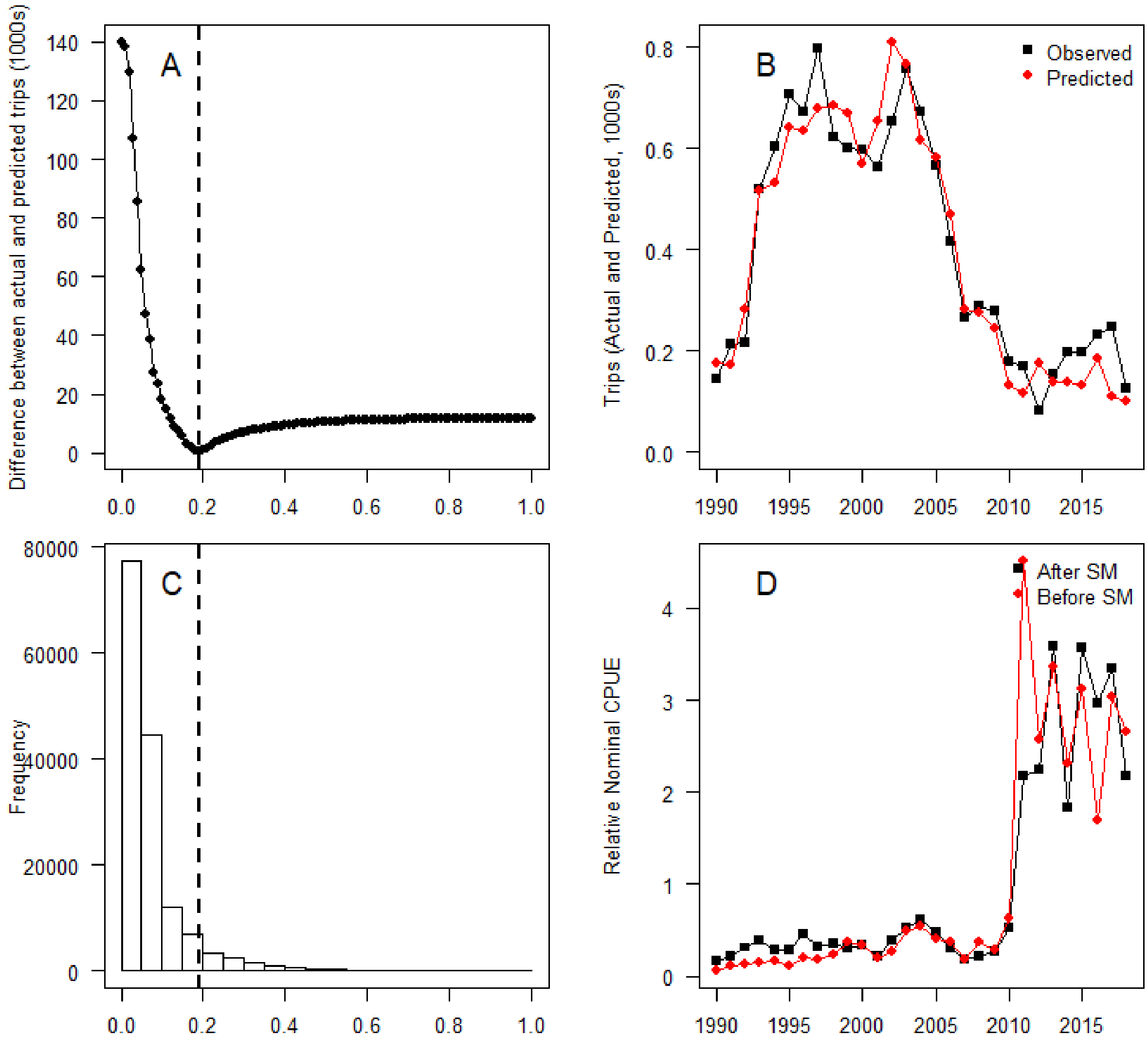

Figure 2. Stephens and MacCall (2004) trip selection diagnostics for the handline for the U.S. GOM. (A) The difference between the number of records in which Greater Amberjack are observed and the number in which they are predicted to occur for each probability threshold; (B) the number of actual and predicted trips; (C) Histogram of probabilities generated by the species-based regression (trips that targeted Greater Amberjack to right of dashed line); and (D) relative 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.

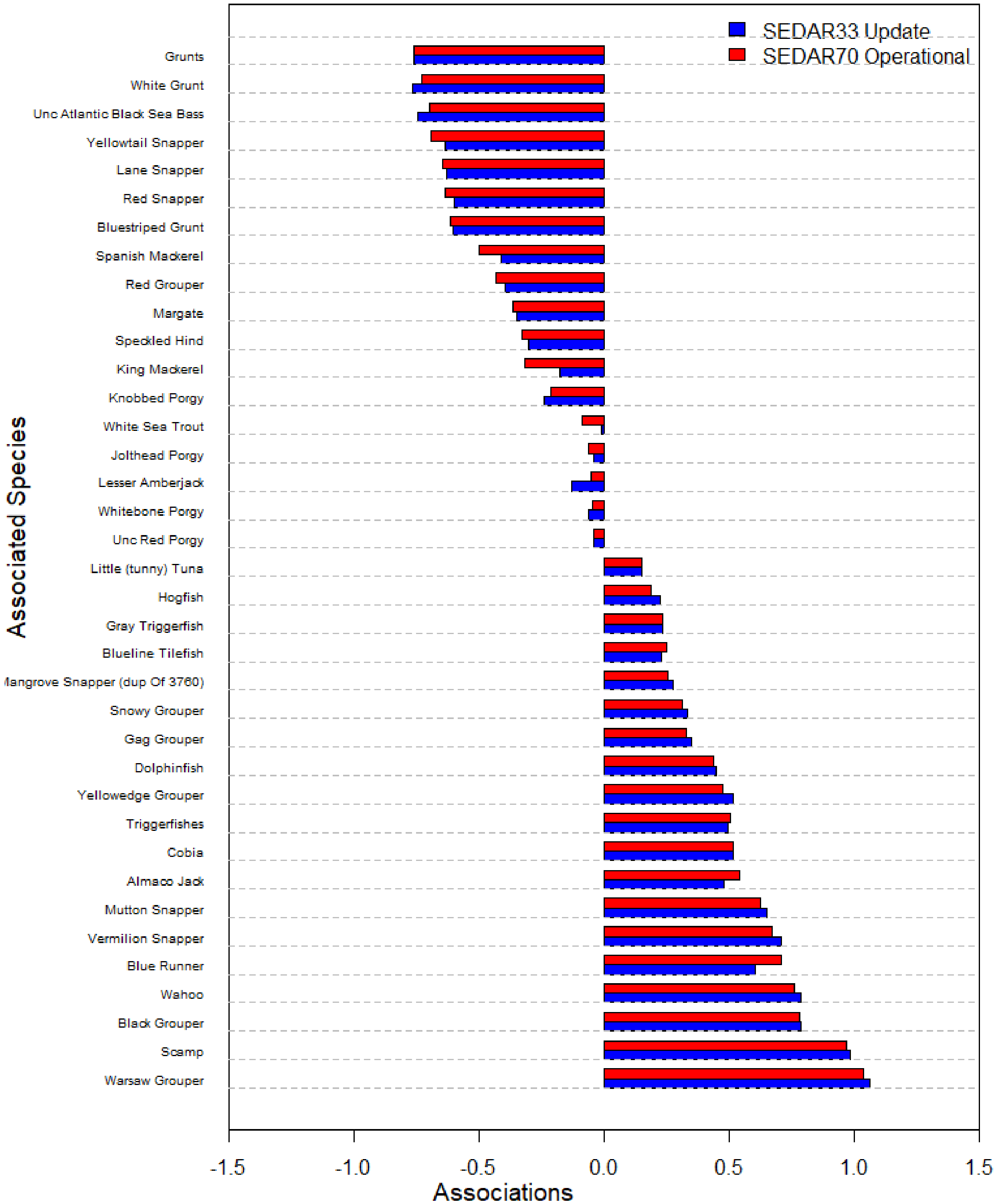

Figure 3. Association coefficients of other species with Greater Amberjack across regions in the U.S. GOM for the handline fishery. Positive numbers indicate a positive correlation.

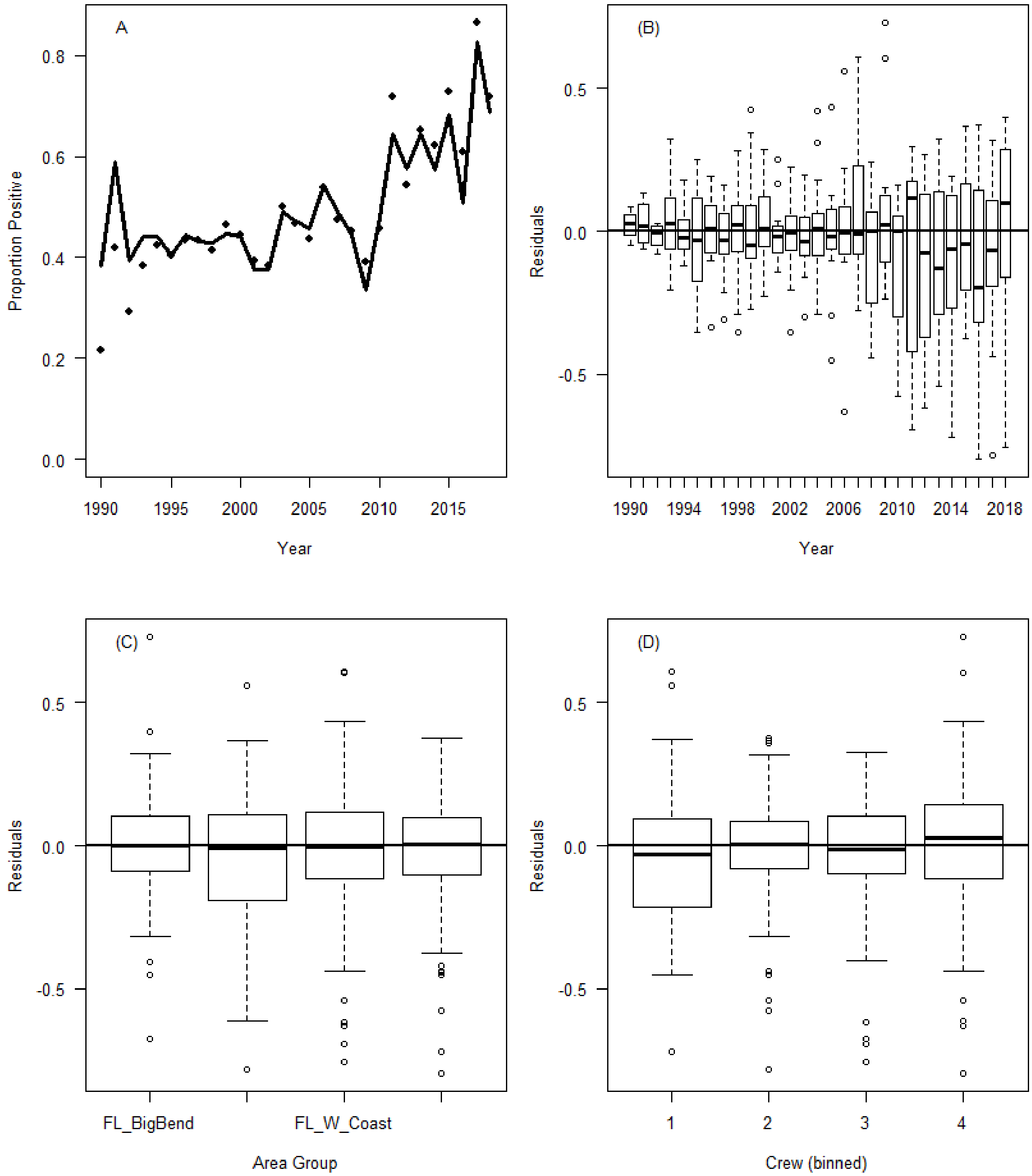

Figure 4. Diagnostic plots for the binomial model for Greater Amberjack in the U.S. GOM for the handline fishery. Shown here are the predicted (solid line) and observed proportion of positive trips by year (A) and the residuals from the binomial model by year (B), area group (C), and crew (D).

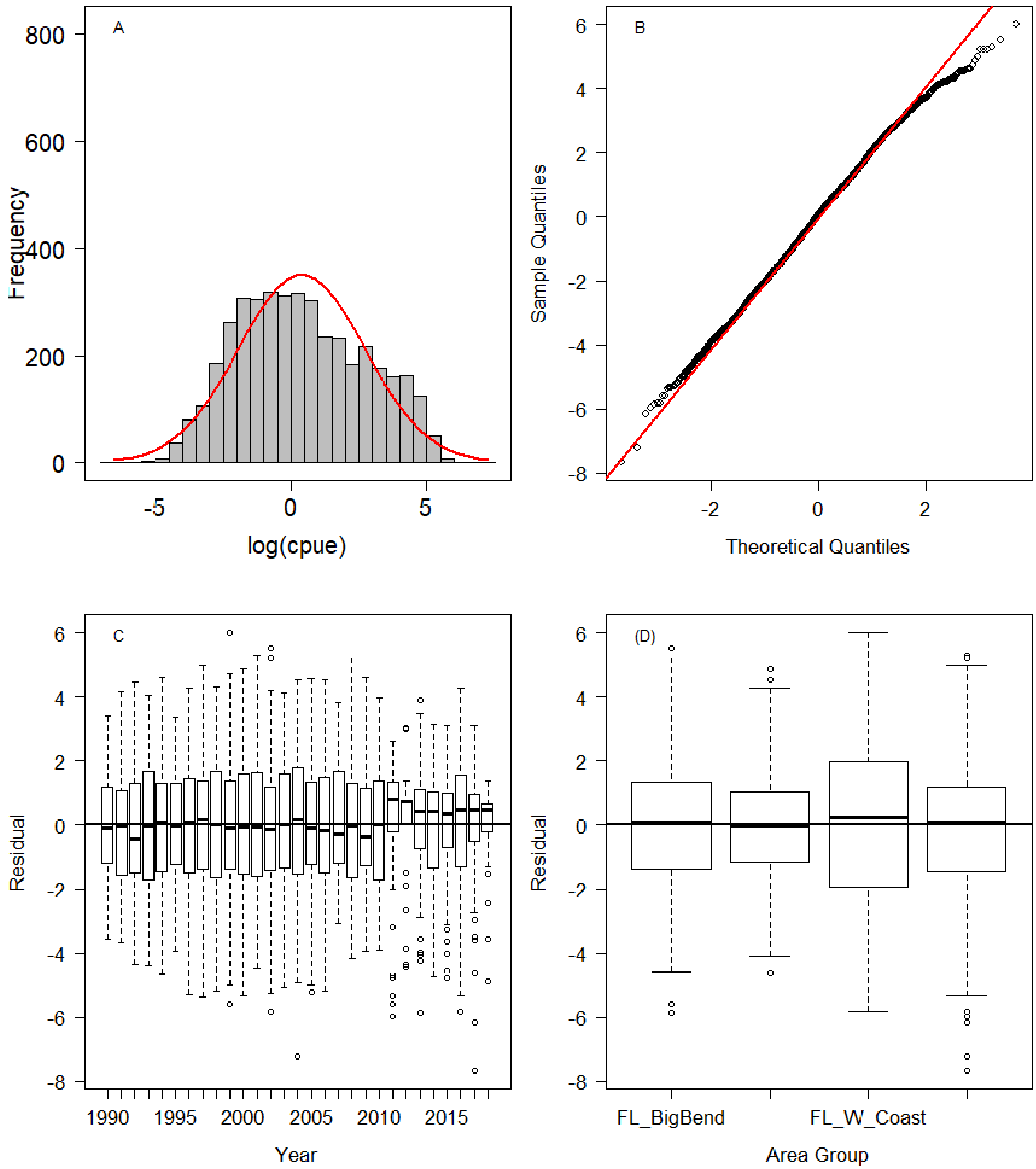

Figure 5. Diagnostic plots for the lognormal model of catch rates on positive trips for Greater Amberjack in the U.S. GOM for the handline fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C) and area group (D). The red lines represent the expected normal distribution.

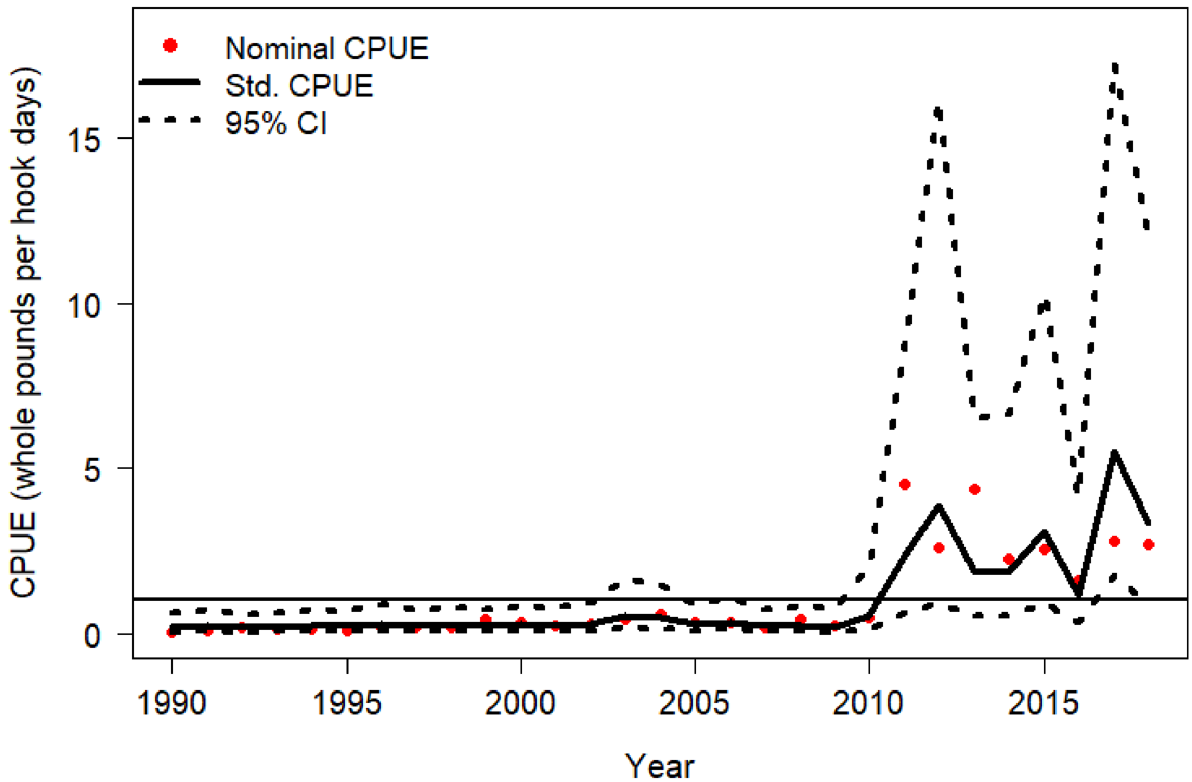

Figure 6. Standardized index with 95% confidence interval, and nominal CPUE for Greater Amberjack in the U.S. GOM for the handline fishery. The index was scaled to the mean value of the entire time series.

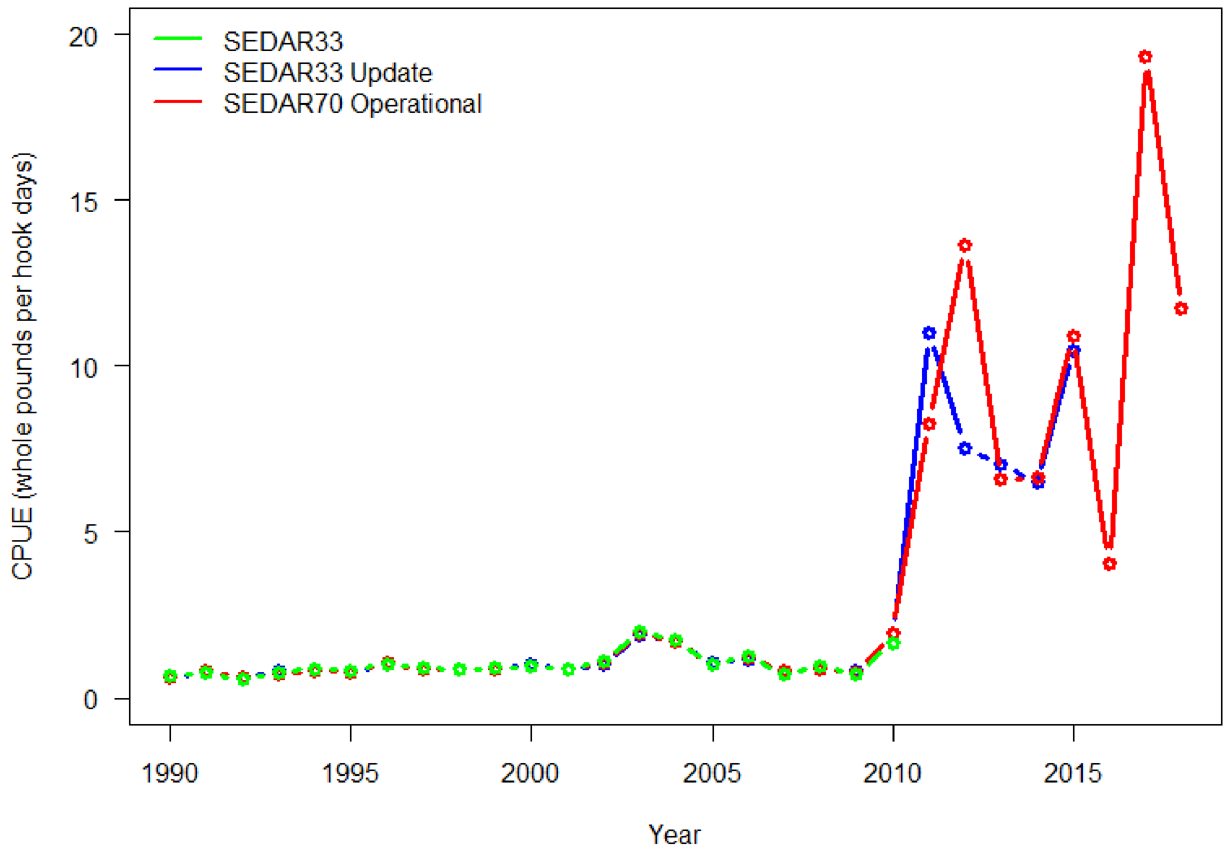

Figure 7. Standardized index for Greater Amberjack in the U.S. GOM for the handline fishery for SEDAR70 compared to the indices provided during SEDAR33 Update and SEDAR33. For comparison, all indices have been normalized by their respective means.

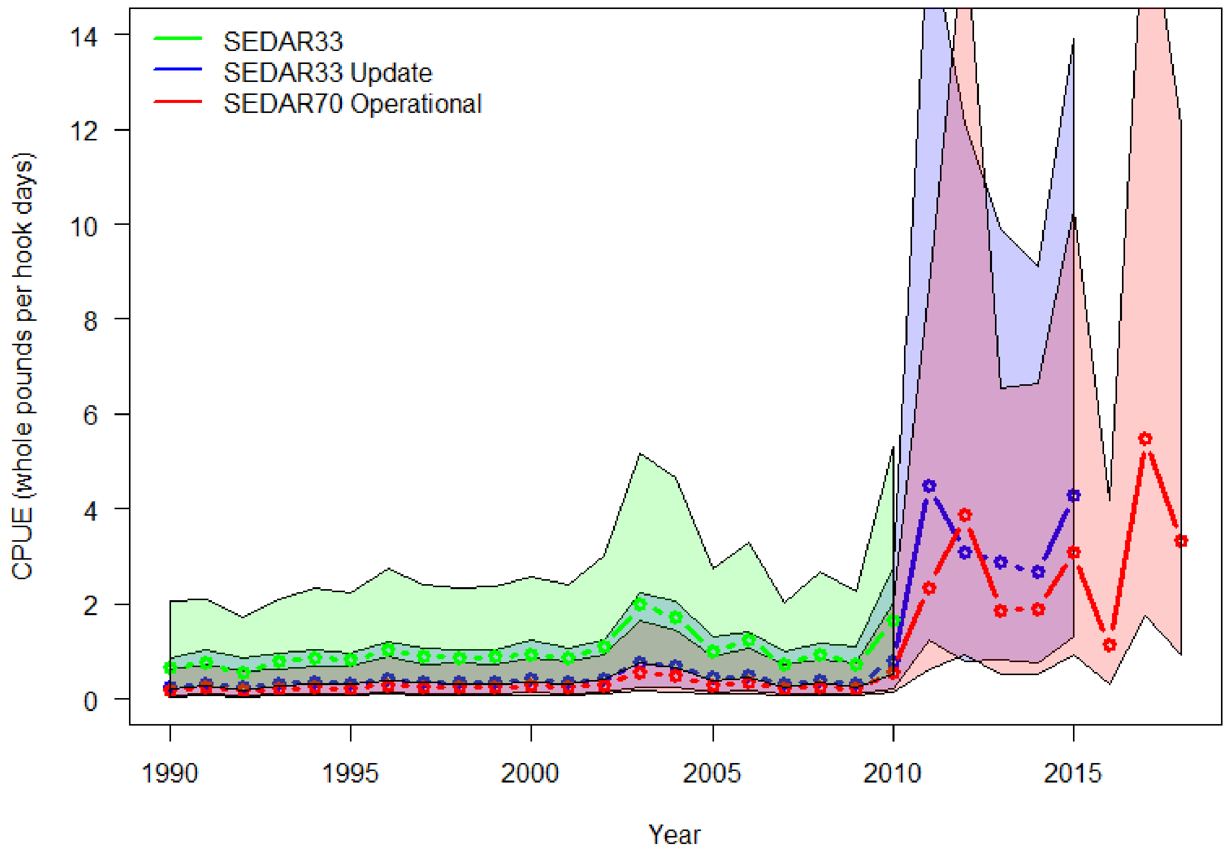

Figure 8. Comparison of indices for Greater Amberjack in the U.S. GOM for the handline fishery with confidence intervals.

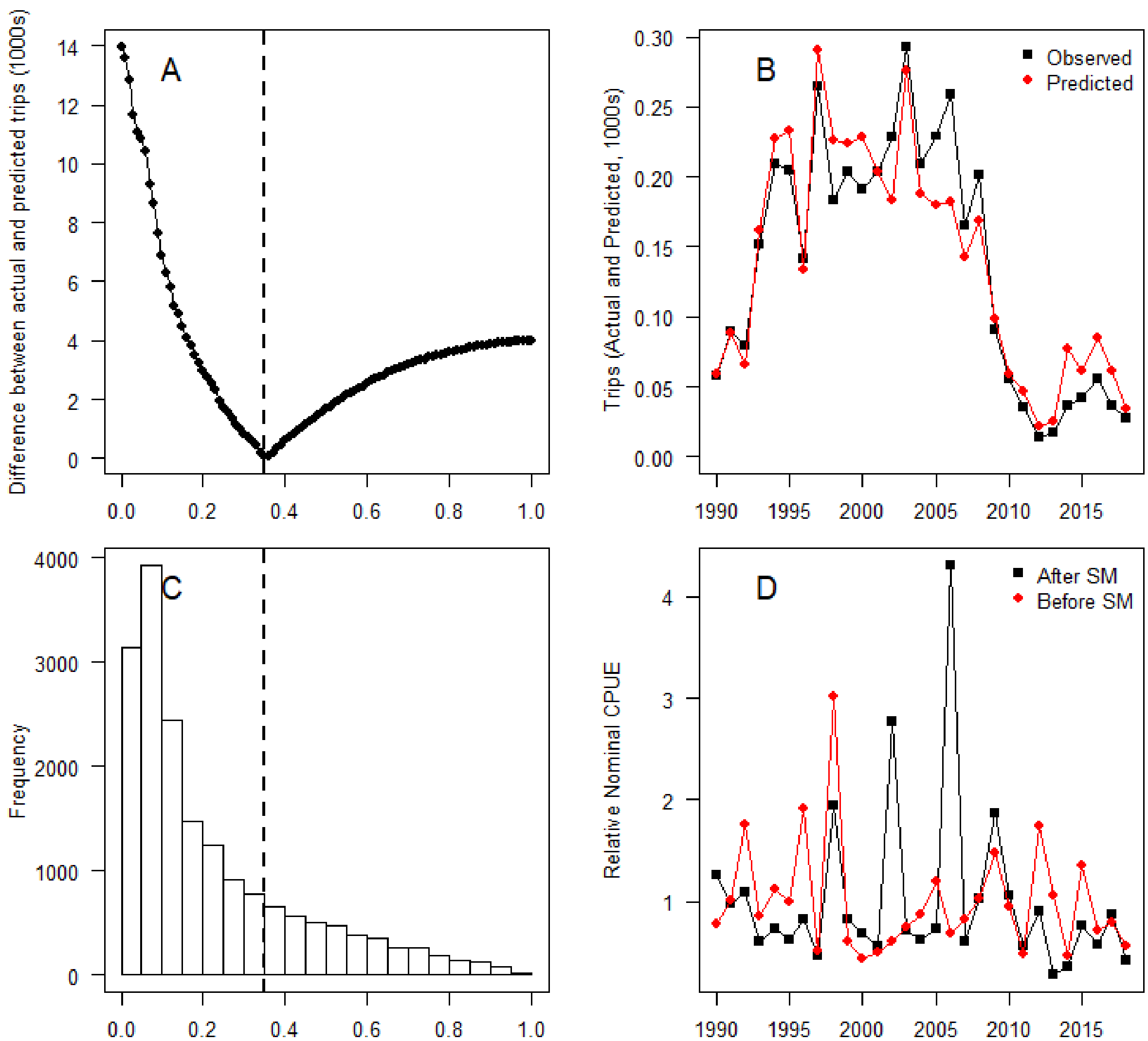

Figure 9. Stephens and MacCall (2004) trip selection diagnostics for the longline for the U.S. GOM. (A) The difference between the number of records in which Greater Amberjack are observed and the number in which they are predicted to occur for each probability threshold; (B) the number of actual and predicted trips; (C) Histogram of probabilities generated by the species-based regression (trips that targeted Greater Amberjack given to right of dashed line); 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.

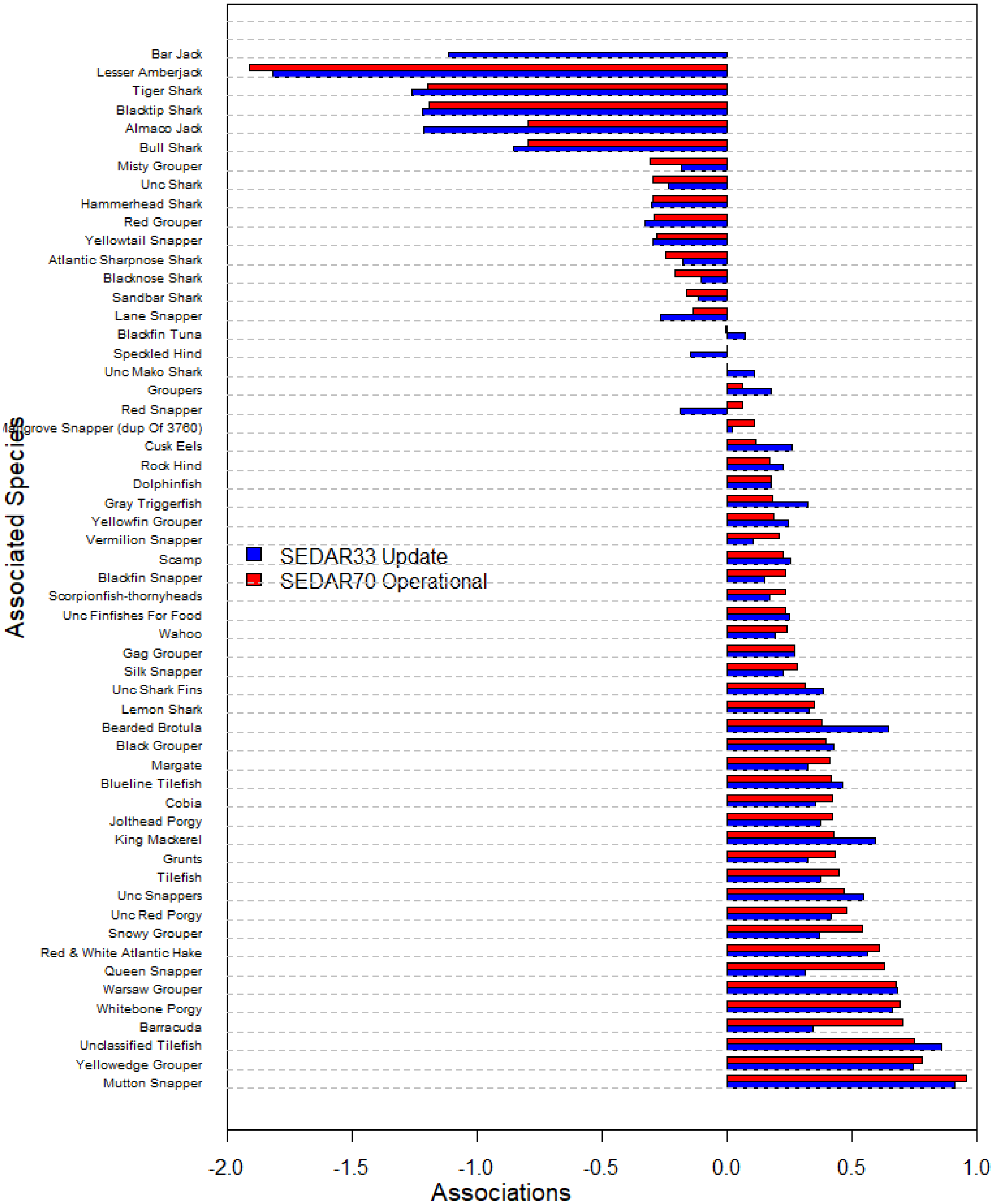

Figure 10. Association coefficients of other species with Greater Amberjack across regions in the U.S. GOM for the longline fishery. Positive numbers indicate a positive correlation.

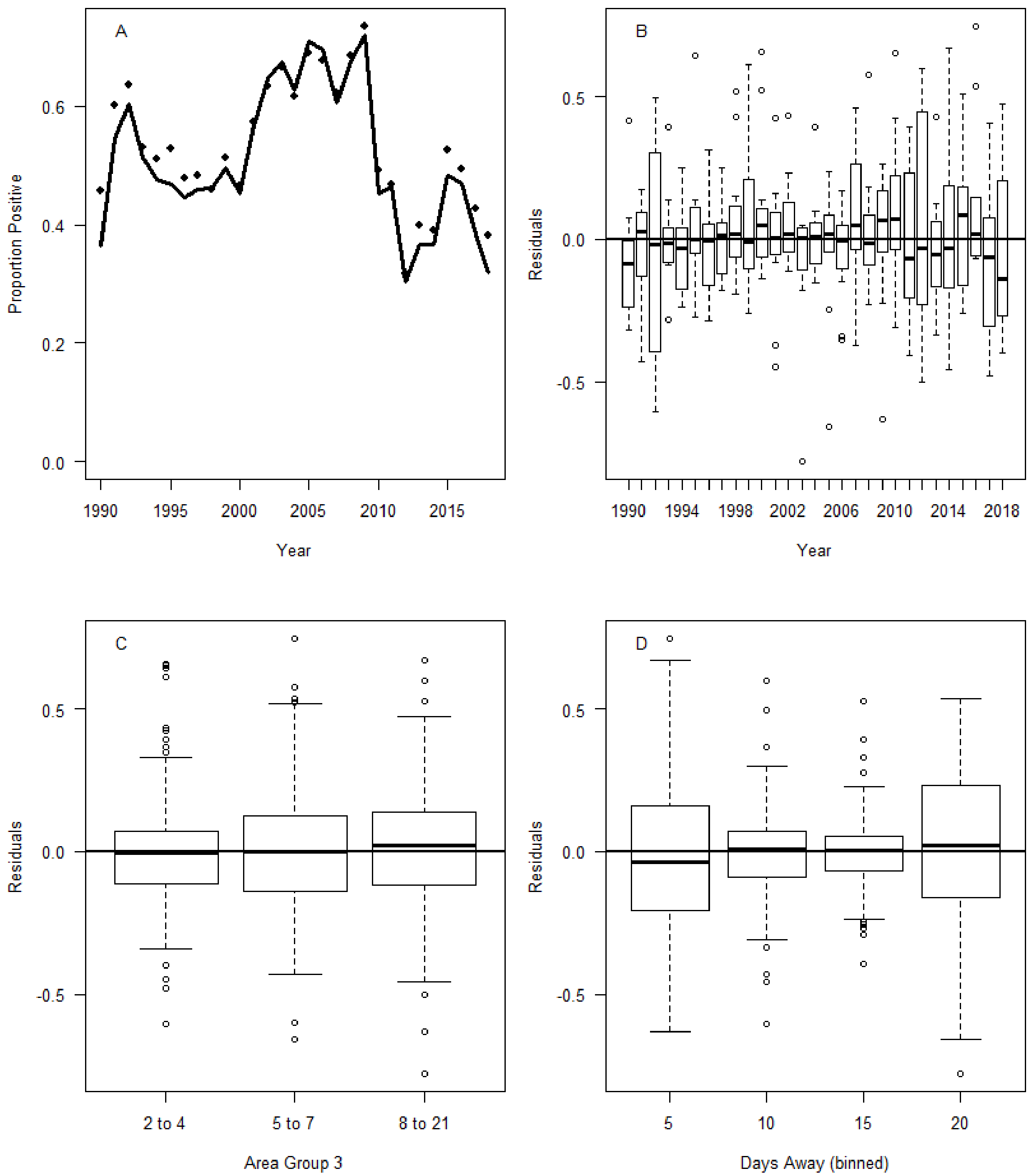

Figure 11. Diagnostic plots for the binomial model for Greater Amberjack in the U.S. GOM for the longline fishery. Shown here are the predicted (solid line) and observed proportion of positive trips by year (A) and the residuals from the binomial model by year (B), area group 3 (C), and days away (D).

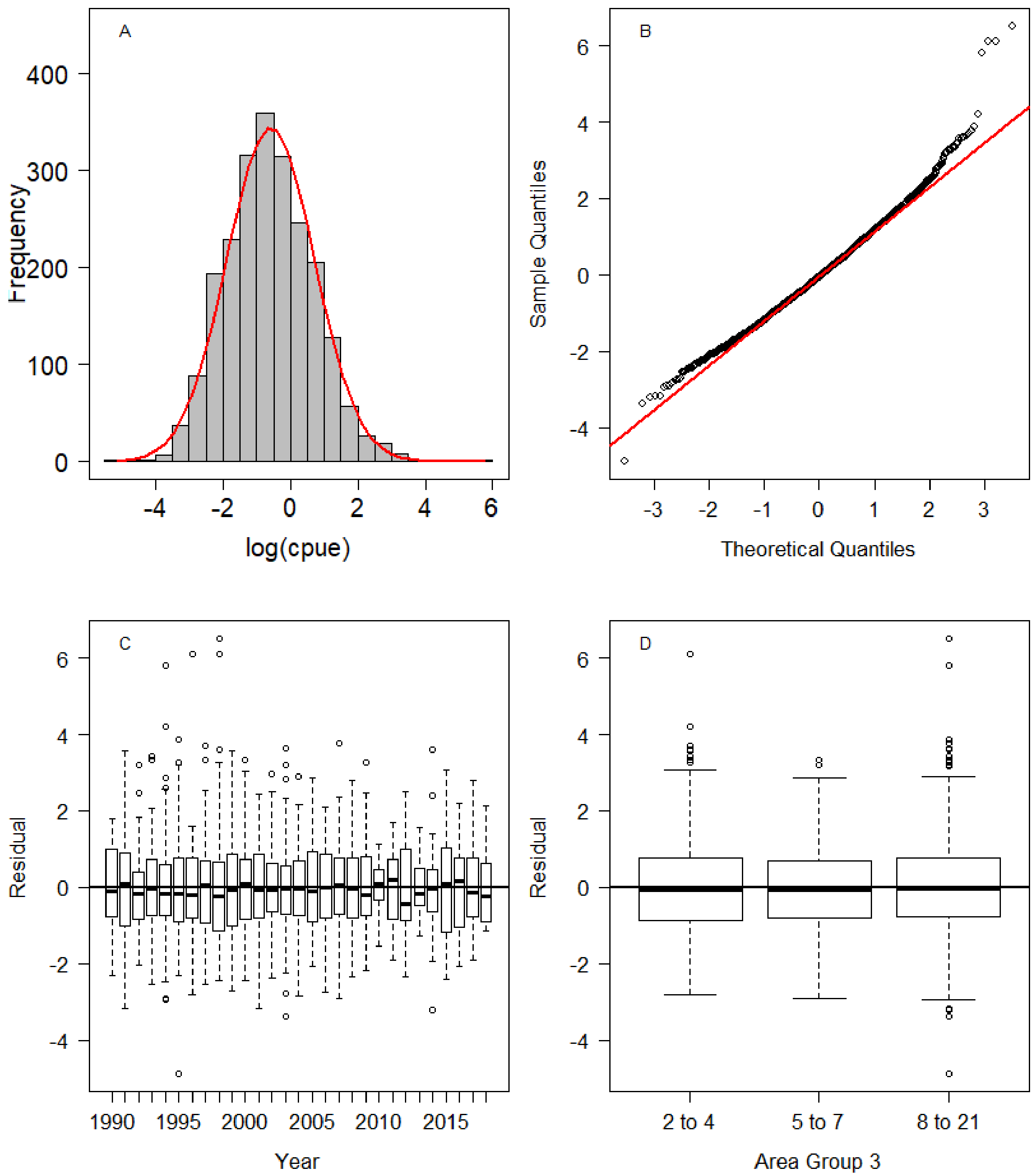

Figure 12. Diagnostic plots for the lognormal model of catch rates on positive trips for Greater Amberjack in the U.S. GOM for the longline fishery. Shown here are the frequency distribution of catch rates (A), the cumulative normalized residuals (B), and the distribution of residuals by year (C) and area group 3 (D). The red lines represent the expected normal distribution.

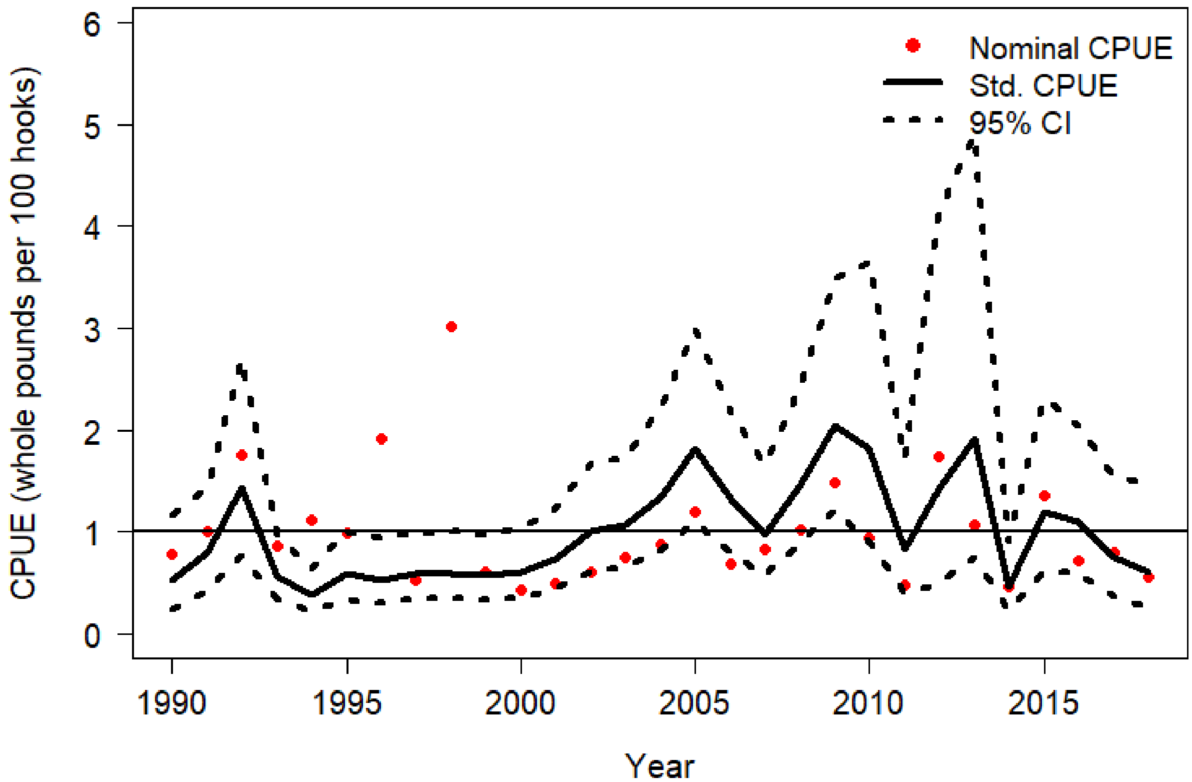

Figure 13. Standardized index with 95% confidence interval, and nominal CPUE for Greater Amberjack in the U.S. GOM for the longline fishery. The index was scaled to the mean value of the entire time series.

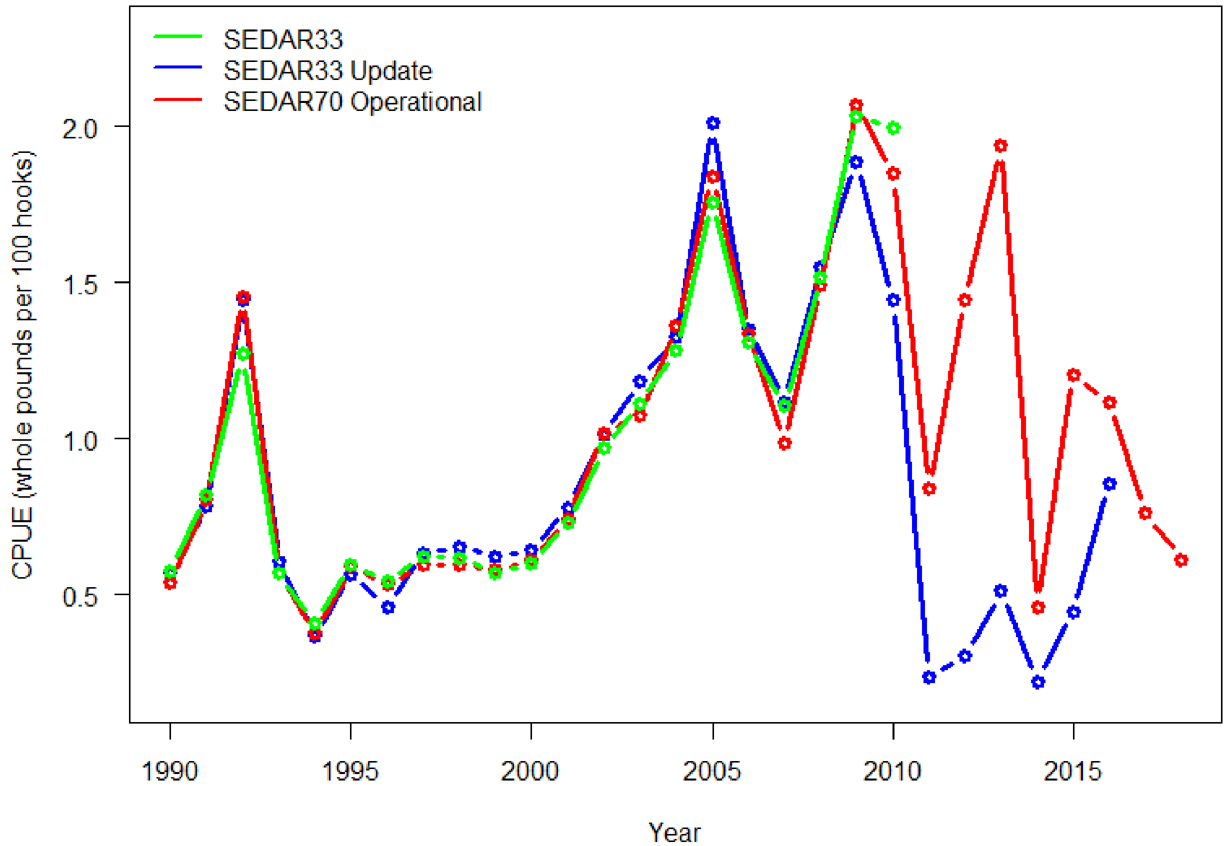

Figure 14. Standardized index for Greater Amberjack in the U.S. GOM for the longline fishery for SEDAR70 compared to the indices provided during SEDAR33 Update and SEDAR33. For comparison, all indices have been normalized by their respective means.

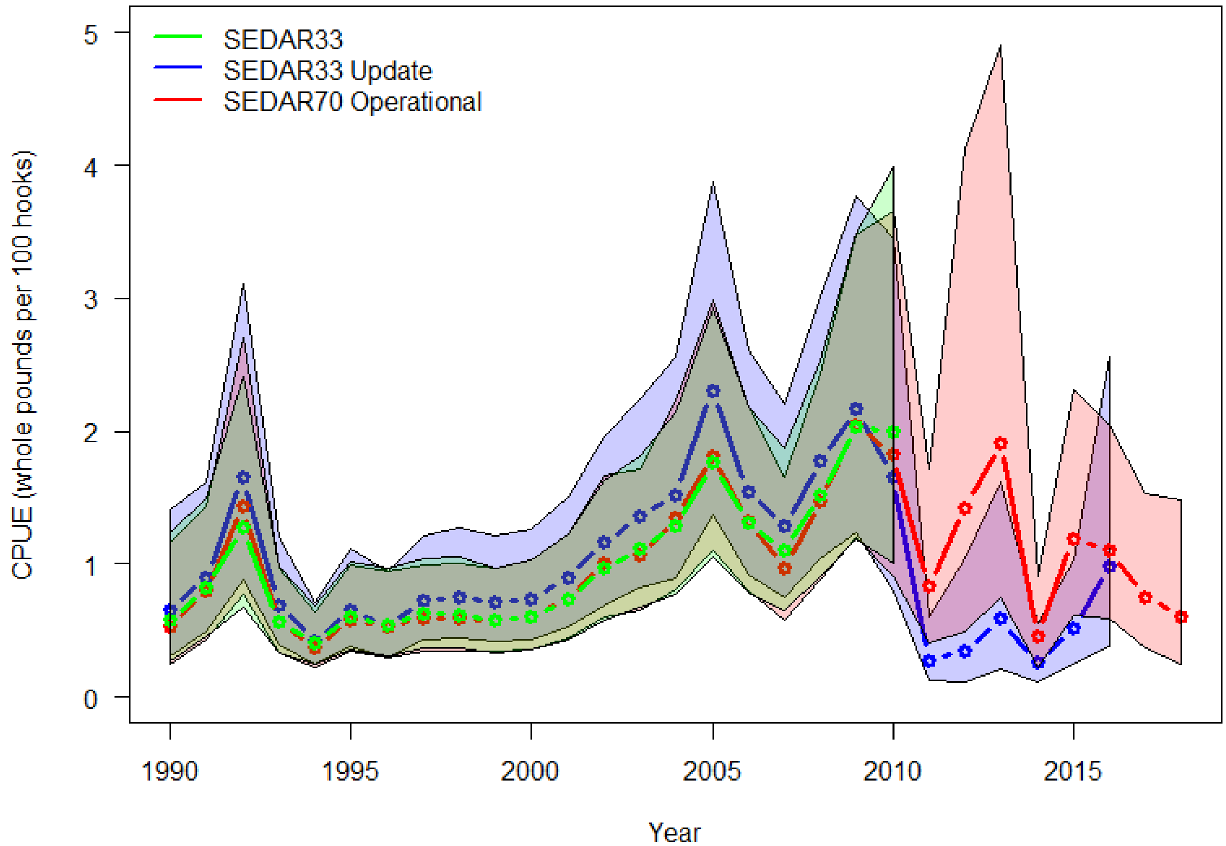

Figure 15. Comparison of indices for Greater Amberjack in the U.S. GOM for the longline fishery with confidence intervals.

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 Greater Amberjack from the handline fishery. The proportion of trips retained is also provided.

Year	Trips Total	Pos Total	PPos Total	Trips SMAC	Pos SMAC	PPos SMAC	Trips Retained
1990	1096	143	0.130	181	39	0.215	0.165
1991	1224	206	0.168	181	76	0.420	0.148
1992	1728	215	0.124	290	85	0.293	0.168
1993	3292	476	0.145	511	196	0.384	0.155
1994	3746	493	0.132	514	218	0.424	0.137
1995	4199	571	0.136	627	253	0.404	0.149
1996	3936	631	0.160	646	280	0.433	0.164
1997	5616	724	0.129	709	307	0.433	0.126
1998	4861	554	0.114	538	222	0.413	0.111
1999	5652	547	0.097	499	232	0.465	0.088
2000	5605	518	0.092	400	177	0.442	0.071
2001	5634	509	0.090	503	198	0.394	0.089
2002	5701	608	0.107	612	235	0.384	0.107
2003	5414	709	0.131	554	277	0.500	0.102
2004	4701	632	0.134	442	206	0.466	0.094
2005	3901	531	0.136	435	190	0.437	0.112
2006	3855	392	0.102	346	186	0.538	0.090
2007	3346	247	0.074	194	92	0.474	0.058
2008	3163	271	0.086	203	92	0.453	0.064
2009	3097	246	0.079	138	54	0.391	0.045
2010	1593	158	0.099	83	38	0.458	0.052
2011	1114	123	0.110	71	51	0.718	0.064
2012	454	73	0.161	46	25	0.543	0.101
2013	651	139	0.214	83	54	0.651	0.127
2014	1573	188	0.120	103	64	0.621	0.065
2015	1058	189	0.179	88	64	0.727	0.083
2016	1070	218	0.204	102	62	0.608	0.095
2017	1013	237	0.234	89	77	0.865	0.088
2018	767	121	0.158	60	43	0.717	0.078

Table A2. Total trips, positive trips (Pos), and proportion of positive trips (PPos) before (Total) and after trip selection (Stephens and MacCall, SMAC) for Greater Amberjack from the longline fishery. The proportion of trips retained is also provided.

Year	Trips Total	Pos Total	PPos Total	Trips SMAC	Pos SMAC	PPos SMAC	Trips Retained
1990	329	58	0.176	59	27	0.458	0.179
1991	388	89	0.229	88	53	0.602	0.227
1992	359	79	0.220	66	42	0.636	0.184
1993	661	152	0.230	162	86	0.531	0.245
1994	956	209	0.219	227	116	0.511	0.237
1995	1118	205	0.183	233	123	0.528	0.208
1996	897	141	0.157	134	64	0.478	0.149
1997	1277	265	0.208	290	140	0.483	0.227
1998	866	183	0.211	226	104	0.460	0.261
1999	1019	204	0.200	224	115	0.513	0.220
2000	922	191	0.207	228	106	0.465	0.247
2001	967	204	0.211	204	117	0.574	0.211
2002	960	228	0.238	183	116	0.634	0.191
2003	1038	293	0.282	276	184	0.667	0.266
2004	1113	209	0.188	188	116	0.617	0.169
2005	1026	229	0.223	180	124	0.689	0.175
2006	1037	259	0.250	182	123	0.676	0.176
2007	610	165	0.270	143	89	0.622	0.234
2008	593	201	0.339	169	116	0.686	0.285
2009	183	91	0.497	98	72	0.735	0.536
2010	180	56	0.311	59	29	0.492	0.328
2011	148	35	0.236	47	22	0.468	0.318
2012	100	14	0.140	22	7	0.318	0.220
2013	243	17	0.070	25	10	0.400	0.103
2014	240	36	0.150	77	30	0.390	0.321
2015	241	42	0.174	61	32	0.525	0.253
2016	266	56	0.211	85	42	0.494	0.320
2017	150	37	0.247	61	26	0.426	0.407
2018	131	27	0.206	34	13	0.382	0.260