Standardized catch rates of Black Grouper, *Mycteroperca bonaci*, for the Southeast Regional Headboat Survey, 1986-2015

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SEDAR48-DW-01

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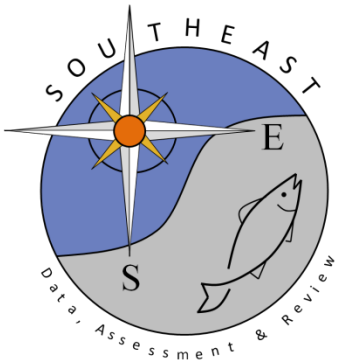

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Introduction

In SEDAR 19, standardized catch rates for Black Grouper for the Southeast Regional Headboat Survey, hereafter called the headboat survey, were calculated from 1979 through 2008. Because the measure of the index was the number of fish landed and not the total catch, the index was broken into two time periods reflecting different size regulations. We are switching assessment models from ASAP (Legault and Retrepo 1998) to Stock Synthesis 3 (Methot and Wetzel 2013) and SS3 allows for indices on the retained catch so there is no longer a need to partition the index. The reviewers also recommended using a single index for the entire time period; therefore, the headboat index is a single index using data from 1986 through 2015. In SEDAR 41 DW46, it was recommended that the potential vessels be evaluated before being included in the data set used to calculate the headboat index.

Methods

Personnel from the Beaufort Lab provided the headboat logbook data set that contains the date, collection number, area, vessel, vessel type, trip type, number of anglers, species, number of fish landed, number fish released, and weight landed in kg. To identify headboat trips that had the potential to catch Black Grouper, I extracted the headboat logbook records (vestype = 1) from 1986 through 2105 from the center of the Black Grouper distribution (areas 11 -- Fort Pierce and 12 -- the Florida Keys). Normally, trips from the Dry Tortugas would have been included but there were no records from the Dry Tortugas after 2012. The basic data were also filtered to remove records with species codes of 0, 999, and missing species codes. After tallying the records by trip and species, there were 618,255 species records from 62,295 headboat trips.

Since the goal of an index is consistency among years and lacking guidance in SEDAR 41 DW46 on filtering vessels, I used a simple process for evaluating whether to include a particular vessel in the final data set. The criteria were that an included vessel had to have more than two years of headboat landings and the vessel had to have Black Grouper landings every year of operation. Thirteen headboats met these two criteria; however, one vessel had two strata with a single value which necessitated its removal. Therefore, there were 12 headboats in the final data set which had 16,478 trips of which 3,168 trips caught Black Grouper (19%) from 1986-2015 (Table 1).

Generating an index using just the trips that landed Black Grouper underestimates the effort exerted for this species. Therefore, the challenge is to identify which additional headboat trips should be included in the analysis because they had the potential to catch Black Grouper. I used the same Stephens and MacCall (2004) multiple logistic regression technique that Conn SEDAR 19 used In SEDAR 19 (DW04) to predict whether Black Grouper could have been caught on a trip. The Stephens and MacCall approach calculates a probability of catching Black Grouper for every trip based on the presence or absence of the other species on the trip and compares the probability to the threshold value that minimized the

difference between the observed and the predicted trips that caught Black Grouper. To simplify the analysis, species that were landed on less than 1% of the trips were omitted from the regression calculations. Figure 1 illustrates the species and their coefficients that were used to calculate the probability of whether a trip had the potential to catch a Black Grouper. Of the 57 species that were included in the full model, only 26 species had coefficients that were statistically significant at an alpha level of 0.05. Possible threshold values over the range of 0 to 1 were evaluated with regard to locating the minimum difference between the observed number of positive trips and the predicted number of positive trips. The threshold value of 0.269 had the lowest difference; thus, trips with a probability greater than 0.269 were included in the standardization analysis (Figure 2).

The standardized mean number of Black Grouper per trip was estimated with a delta-gamma model (Lo et al. 1992) that involved two generalized linear submodels (GLIM). The first submodel estimated the probability that a headboat trip would catch a Black Grouper with a binomial distribution (logit link) and the second submodel estimated the number of Black Grouper caught on successful trips using a gamma distribution (log link). The annual index is the product of these two terms by year after they each have been back-calculated from their linear forms (for the logit link, the transform was $\Pr op = \frac{e^{f(x1+x2+..)}}{1+e^{f(x1+x2+...)}}$ and for the gamma, the transform was $Y = e^{g(x1+x2+...)}$ where the x1, x2,… refer to the variables included in the respective linear models). Potential variables to be included in the models were year, month, vessel, area (Southeast Florida or the Florida Keys), adjusted trip type, and the number of anglers. The number of anglers was subdivided into 10-angler bins and the few trips with more than 50 anglers were grouped into a 50+ category. Time fished is not recorded for each headboat trip but the trip type contains the trip duration in hours; half day trips were assumed to have fished five hours, three-quarter day trips fished seven hours, full day trips fished for nine hours, and multi-day trips fished for 12 hours per day. The use of categories can account for non-linearity in the catch-rate response. In SEDAR 19, the response variable was the number fish per trip per angler-hour while in the current analysis, the response variable is the number of Black Grouper per trip and the components of effort, the number of anglers and time, are included in the model only if they meet the criteria for including variables given below..

The submodels used a forward stepwise process to identify which variables to include in the respective submodels. For a variable to be included in the final model, the variable had to meet two criteria: the variable had to be statistically significant at the 0.05 level (chance of observing value if its actual value was zero) and it had to reduce the deviance (a measure of the variability) by at least 0.5%.

To calculate the year-specific index and its variability, I used a Monte Carlo simulation approach with 10,000 iterations that used the least-squares mean estimates and their standard errors from the GLIM models. Each iteration used the annual least-squares mean catch rate and added uncertainty that was calculated by multiplying the standard error by a random normal deviate (μ=0, σ=1). As described above, these values were converted back from their linear scale and multiplied together.

Results and Discussion

There were 3,081 trips selected by the Stephens and MacCall process and of those trips 834 landed Black Grouper (an average of 27%). Thus, the estimated effort for Black Grouper was 3.7 times that of the trips landing Black Grouper confirming that just using Black Grouper trips would have

underestimated that effort that was expended for Black Grouper. The binomial submodel, estimating the proportion of positive trips each year, identified vessel and year as significant variables and the final submodel reduced the deviance by 13.5%. The submodel estimating the number of Black Grouper caught on positive headboat trips identified vessel, year, and month as significant variables and the final submodel reduced the deviance by 27.4%. The least-square means for the two submodels were not correlated (*r = 0.30, df = 28, P = 0.10*). An alternative submodel for the number of Back Grouper on a trip was run using a log-normal distribution with an identity link but the results of that submodel only had vessel as the significant variable and the model reduced the deviance by 20.0%.

The catch rates increased from 1988 (0.10 Black Grouper per trip, *CV* = 1.108) reaching a peak in 2005 (1.71 Black Grouper per trip, 0263) then declined until 2013 (0.29 Black Grouper per trip, 0.344) and turned up afterwards (Fig.3 and Table 3). The standardized catch rate in 2015 was 0.49 Black Grouper per trip, *CV* = 0.327). The large coefficients of variation in the early years reflect the low sample sizes. As a check on the catch rates, the nominal catch rates were superimposed on the standardized catch rates and their confidence intervals and the nominal rates fell mostly within the confidence intervals (Figure 4).

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

Table 1. The number of headboat trips in areas 11 and 12 (Southeast Florida and the Florida Keys) , number of vessels, mean number caught per trip , and its standard deviation and standard error for the trips that were made by vessels that operated for more than two years and landed Black Grouper every year of their operation.

Year	Trips	Vessels	Mean number	SD	SE
1986	32	4	1.13	0.331	0.058
1987	65	3	1.26	0.790	0.098
1988	39	3	1.23	0.576	0.092
1989	112	3	1.29	0.604	0.057
1990	23	2	1.35	0.560	0.117
1991	5	2	1.00	0.000	0.000
1992	41	4	1.39	0.793	0.124
1993	49	4	1.24	0.590	0.084
1994	55	4	1.62	1.104	0.149
1995	72	4	1.68	1.141	0.134
1996	64	5	1.50	1.146	0.143
1997	73	4	1.59	1.180	0.138
1998	64	5	1.80	1.078	0.135
1999	126	3	1.79	1.467	0.131
2000	47	3	1.74	1.061	0.155
2001	83	3	2.54	6.266	0.688
2002	46	3	1.80	1.154	0.170
2003	56	4	2.93	2.178	0.291
2004	114	4	3.06	2.593	0.243
2005	98	4	2.34	1.518	0.153
2006	72	3	1.86	2.485	0.293
2007	73	3	1.27	1.598	0.187
2008	86	3	1.31	1.572	0.170
2009	179	3	0.95	1.540	0.115
2010	219	4	1.24	1.514	0.102
2011	138	4	1.79	1.998	0.170
2012	177	5	1.28	1.235	0.093
2013	334	6	1.11	1.654	0.091
2014	391	6	0.84	1.274	0.064
2015	235	6	1.78	2.691	0.176
	3168				

Table 2. Number of vessels, number of trips, number of trips that landed Black Grouper, and the ratio of Black Grouper trips to number of trips by year for the data selected by the Stephens and MacCall approach.

Year	Number of vessels	Number of trips	Number of trips that landed Black Grouper	Black Grouper trips / number of trips
1986	3	16	5	0.313
1987	3	39	5	0.128
1988	3	19	1	0.053
1989	3	153	42	0.275
1990	2	35	7	0.200
1991	1	2	1	0.500
1992	2	10	1	0.100
1993	3	38	4	0.105
1994	3	17	7	0.412
1995	3	13	2	0.154
1996	3	30	7	0.233
1997	4	65	19	0.292
1998	3	41	14	0.341
1999	3	38	15	0.395
2000	3	104	22	0.212
2001	3	69	33	0.478
2002	3	73	33	0.452
2003	4	34	16	0.471
2004	4	46	21	0.457
2005	4	48	22	0.458
2006	3	145	60	0.414
2007	2	73	19	0.260
2008	2	48	13	0.271
2009	3	239	69	0.289
2010	4	241	65	0.270
2011	4	180	41	0.228
2012	5	313	80	0.256
2013	6	324	55	0.170
2014	6	341	89	0.261
2015	6	288	67	0.233
		3082		

Table 3. Standardized headboat index (catch rates), their coefficient of variation, number of trips, and number of positive trips by year

Year	Index Number per trip	Index Scaled to mean	CV	Number of trips	Number of positive trips
1986	0.50	0.72	0.733	16	5
1987	0.33	0.47	0.861	39	5
1988	0.11	0.15	1.124	19	1
1989	0.36	0.51	0.534	153	42
1990	0.39	0.56	0.738	35	7
1991	0.74	1.06	0.573	2	1
1992	0.19	0.27	0.995	10	1
1993	0.29	0.41	0.997	38	4
1994	0.79	1.12	0.616	17	7
1995	1.04	1.48	3.557	13	2
1996	0.58	0.82	0.415	30	7
1997	0.81	1.16	0.314	65	19
1998	1.12	1.60	0.346	41	14
1999	1.07	1.52	0.323	38	15
2000	0.63	0.89	0.342	104	22
2001	1.27	1.81	0.250	69	33
2002	0.95	1.35	0.264	73	33
2003	1.22	1.73	0.371	34	16
2004	1.61	2.29	0.275	46	21
2005	1.71	2.44	0.262	48	22
2006	1.35	1.93	0.246	145	60
2007	1.31	1.86	0.314	73	19
2008	0.76	1.08	0.323	48	13
2009	1.01	1.44	0.251	239	69
2010	0.72	1.03	0.261	241	65
2011	0.85	1.22	0.290	180	41
2012	0.61	0.87	0.264	313	80
2013	0.29	0.42	0.343	324	55
2014	0.38	0.54	0.308	341	89
2015	0.49	0.70	0.329	288	67
				3082	835

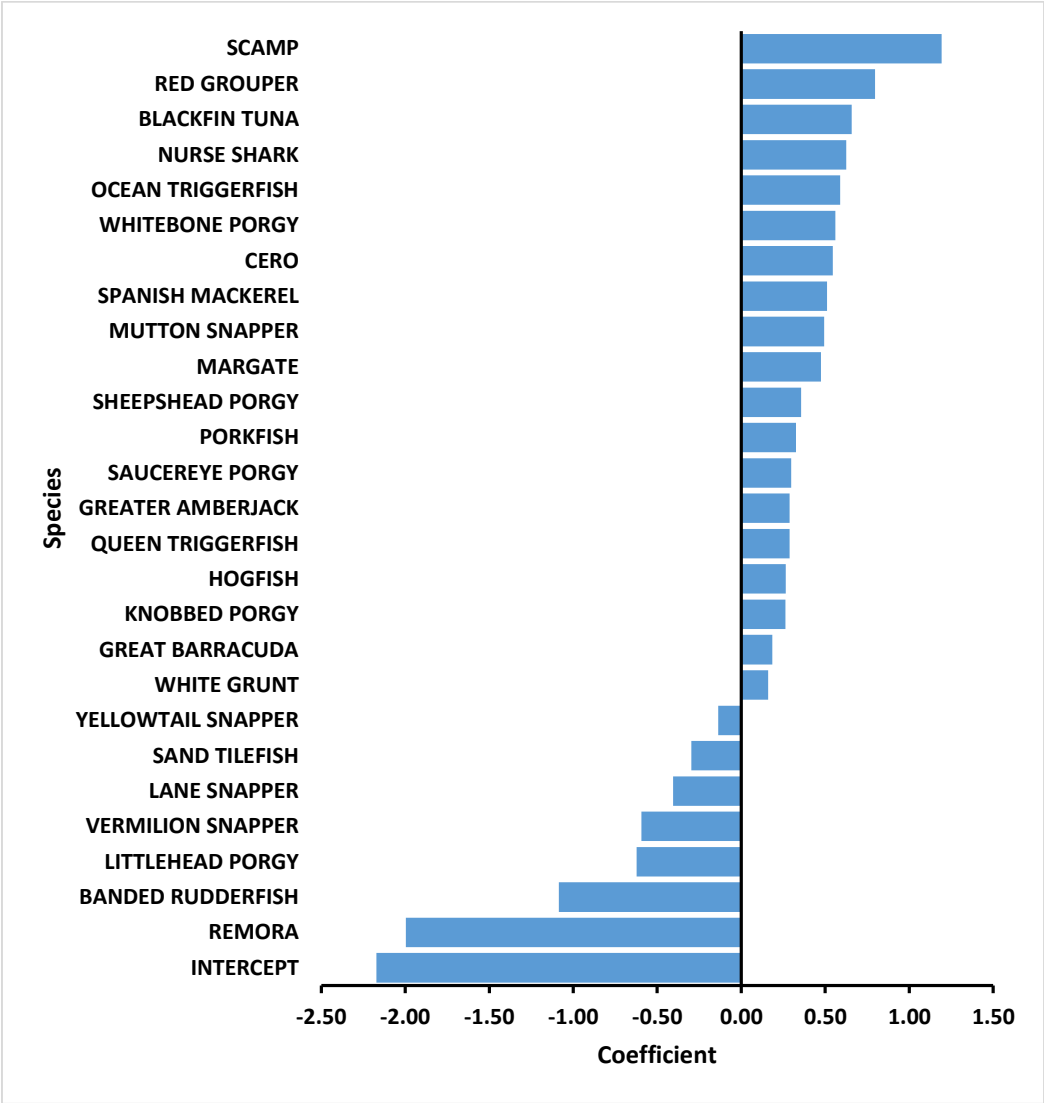

Figure 1. The logistic regression coefficients for the species used to estimate whether catching Black Grouper was likely on each trip.

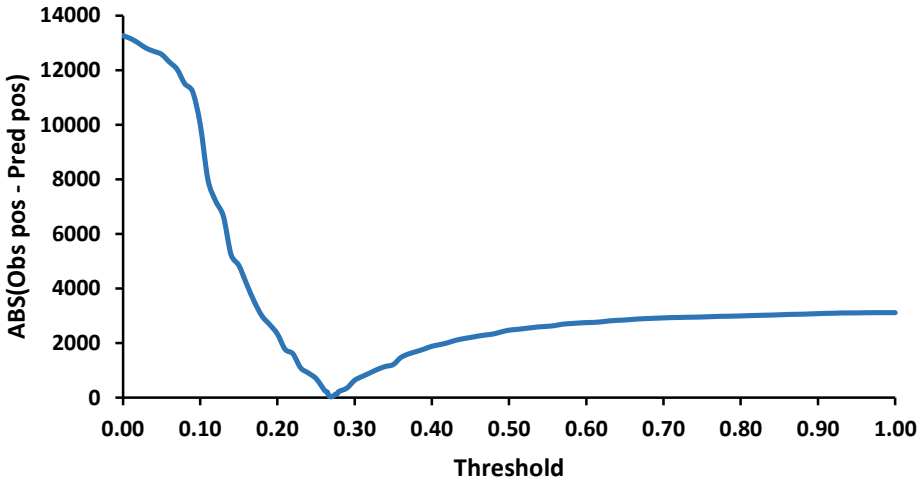

Figure 2. Identifying the threshold value associated with the minimum difference between the observed number of positive trips and the predicted number of positive trips.

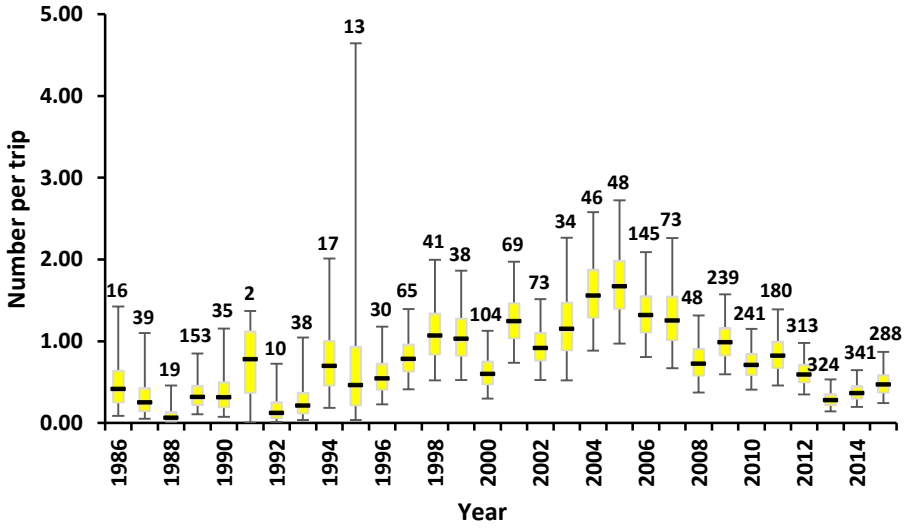

Figure 3. Box plot of the standardized Black Grouper headboat catch rates. The horizontal line is the median estimate; the box is the inter-quartile range, and the vertical line is the 95% confidence interval. The number of trips by year is shown above the confidence interval.

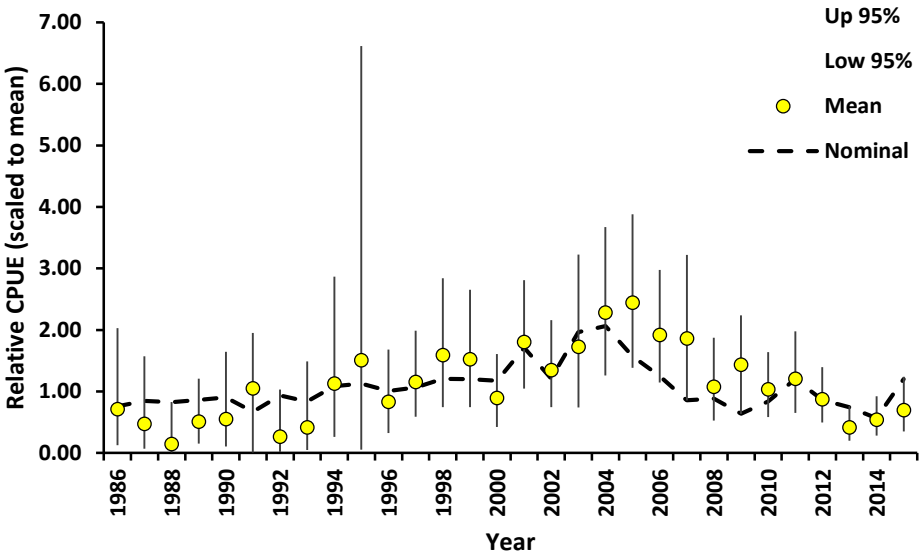

Figure 4. Comparison of standardized catch rates with their confidence intervals and nominal catch rates by year

Addendum to the standardized catch rates of Black Grouper, *Mycteroperca bonaci*, for the Southeast Regional Headboat Survey, 1986-2015

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Introduction

The Data Workshop for SEDAR 48 was held on 15-17 Mar 2017 in St. Petersburg, FL and when the Southeast Regional Headboat Survey, hereafter called the headboat survey, was discussed by the Index Committee, the committee recommended three primary modifications. Firstly, the definition of headboat area 12 (the Florida Keys) was expanded in 2013 to include the Dry Tortugas (formerly denoted as area 17). In SEDAR 48-DW-01, it was noted that trips to the Dry Tortugas were not considered in the analyses because there were no trips after 2012. Actually there were trips; however, the trips were included in area 12. The second recommendation was not to consider vessels to be indicative of consistent fishing behavior because there is high turnover of headboat captains, sometimes even within a single season. The third recommendation was to exclude trips conduced in January through April because the South Atlantic implemented a spawning season closure (March 1-April 30) in the Exclusive Economic Zone (EEZ) for Black Grouper, Gag, and Red Porgy on February 24, 1999 which was expanded (January 1-April 30) on July 29, 2009 which affects the commercial and recreational fishery sectors. While Black Grouper might still be caught, retention was not allowed so there would be no legal landings during the spawning season from the EEZ. This addendum addresses the Index Committee's three recommendations.

Methods

As before, we used the headboat captain's logbook dataset which contains the trip date, collection number, area, vessel, vessel type, trip type, number of anglers, species, number of fish landed, number fish released, and weight landed in kg. To identify headboat trips that had the potential to catch Black Grouper, we extracted the headboat logbook records (vestype = 1) from 1986 through 2015 from the center of the Black Grouper distribution (areas 11 -- Fort Pierce and 12 -- the Florida Keys and Dry Tortugas. These data were also filtered to remove records with species codes of 0, 999, and missing species codes and trips from January through April. After tallying the records by trip and species, there were 446,705 species records from 47,380 headboat trips and anglers on 4,040 trips that landed Black Grouper.

Originally, the headboat data were restricted to vessels that had been in the headboat fishery for three or more years and caught Black Grouper every year. It was pointed out during discussion of the headboat index that the turnover in captains within the fleet nullified the underlying assumption that a vessel was fished in a similar manner from year to year; therefore, vessels were not considered further in the analyses.

As before, we identified additional headboat trips that had the potential to catch Black Grouper using the same Stephens and MacCall (2004) multiple logistic regression technique that we used in the

original standardization (Muller and O'Hop 2017) and Conn (2009) used In SEDAR 19 (DW04) to predict whether Black Grouper could have been caught on a trip. Figure 1 illustrates the species and their coefficients that were used to calculate the probability of whether a trip had the potential to catch a Black Grouper. Of the 69 species that were included in the full model, only 43 species had coefficients that were statistically significant at an alpha level of 0.05. Possible threshold values over the range of 0 to 1 were evaluated with regard to locating the minimum difference between the observed number of positive trips and the predicted number of positive trips. The threshold value of 0.263 had the lowest absolute difference (4 trips); thus, trips with a probability greater than 0.263 were included to minimize the number of false positives (trips predicted to have landed Black Grouper that did not actually land Black Grouper) and false negatives (trips predicted not to have landed Black Grouper but did actually land Black Grouper) in the standardization analysis (Figure 2).

The standardized mean number of Black Grouper per trip was estimated with a delta-gamma model (Lo et al. 1992) that involved two generalized linear submodels (GLIM). The first submodel estimated the probability that a headboat trip would catch a Black Grouper with a binomial distribution (logit link) and the second submodel estimated the number of Black Grouper caught on successful trips using a gamma distribution (log link). The annual index is the product of these two terms by year after they each have been back-calculated from their linear forms (for the logit link, the transform was $\Pr op = \frac{e^{f(x1+x2+..)}}{1+e^{f(x1+x2+...)}}$ and for the gamma, the transform was $Y = e^{g(x1+x2+...)}$ where the x1, x2,… refer to the variables included in the respective linear models). Potential variables to be included in the models were year, month, area (Southeast Florida or the Florida Keys), adjusted trip type, trip duration in hours, and the number of anglers. The number of anglers was subdivided into 5-angler bins up to 50 anglers and then by 10 anglers per bin. However, there were only two trips in the 70-79 angler bin and that bin was grouped into a 60+ angler bin. Time fished is not recorded for each headboat trip but the trip type contains the trip duration in hours; half day trips were assumed to have fished five hours, three-quarter day trips fished seven hours, full day trips fished for nine hours, and multi-day trips fished for 12 hours per day. The use of categories can account for non-linearity in the catch-rate response. In SEDAR 19, the response variable was the number fish per trip per angler-hour while in the current analysis, the response variable is the number of Black Grouper per trip and the components of effort, the number of anglers and time, are included in the model only if they meet the criteria for including variables given below..

The submodels used a forward stepwise process to identify which variables to include in the respective submodels. For a variable to be included in the final model, the variable had to meet two criteria: the variable had to be statistically significant at the 0.05 level (chance of observing value if its actual value was zero) and it had to reduce the deviance (a measure of the variability) by at least 0.5%.

To calculate the year-specific index and its variability, we used a Monte Carlo simulation approach with 10,000 iterations that used the least-squares mean estimates and their standard errors from the GLIM models. Each iteration used the annual least-squares mean catch rate and added uncertainty that was calculated by multiplying the standard error by a random normal deviate (μ=0, σ=1). As described above, these values were converted back from their linear scale and multiplied together.

Results and Discussion

There were 4,040 headboat trips in Southeastern Florida, the Florida Keys, and the Dry Tortugas that landed Black Grouper out of 47,380 trips (Table 1). The Stephens and MacCall process selected 4,033 trips and of those trips, anglers on 1,554 trips landed Black Grouper (an average of 39%; Table 2). Thus, the estimated effort for Black Grouper was almost three times that of the trips landing Black Grouper confirming that just using Black Grouper trips would have underestimated that effort that was expended for Black Grouper. The binomial submodel, estimating the proportion of positive trips each year, identified trip duration in hours and year as significant variables in the final submodel that reduced the deviance by 8.0% (Table 3). The standardized deviance residuals did not show a pattern with years but they were distributed in a bimodal pattern (Fig.3) and the q-q plot was not linear. The submodel estimating the number of Black Grouper caught on positive headboat trips identified trips duration in hours, year, months, and the angler categories as significant variables in the final submodel that reduced the deviance by 21.2% (Table 4). For the number of Black Grouper landed on successful trips, the standardized residuals did not show a pattern with years but there eight large positive outliers (Fig 3). The least-square means for the two submodels were not correlated ($r = 0.020, df = 28, P = 0.92$).

Two alternative submodels for the number of Black Grouper landed on a trip were run using a log-normal distribution and with a Poisson distribution. The log-normal distribution with an identity link had the lowest range of standardized residuals (-2.20 to 5.59) and reduced the deviance by 14.0%. The submodel with the Poisson distribution (log link) reduced the deviance by 20.4% but its range of standardized residuals was very wide (-2.94 to 14.09). The gamma distribution reduced the deviance by slightly more than the Poisson distribution (21.2%) and its range of standardized residuals was narrower than the Poisson distribution (-2.19 to 8.28). The q-q plots for the three distributions (gamma, log-normal, and Poisson) were similar.

The catch rates were variable and without trend (slope with year was -0.010, $t = -0.84, df = 28, P = 0.41$) and the coefficient of variations ranged mostly from 0.09 to 0.24 with the exception of 2.75 in 1990 when there were only three trips and two landed Black Grouper (Table 2, Fig. 4). The standardized catch rate in 2015 2.30 Black Grouper per trip, $CV = 0.183$). The large coefficients of variation reflect low sample sizes. As a check on the catch rates, the nominal catch rates were superimposed on the standardized catch rates and their confidence intervals and the nominal rates fell mostly within the confidence intervals (Figure 5).

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

Table 1. The number of headboat trips in areas 11 and 12 (Southeast Florida, the Florida Keys, and the Dry Tortugas) , number of vessels, mean number of Black Grouper landed per trip , and the standard deviation and standard error for the trips that landed Black Grouper.

Year	Trips	Vessels	Mean number	SD	SE
1986	138	21	2.29	2.852	0.243
1987	122	18	2.91	5.900	0.534
1988	68	16	1.49	1.989	0.241
1989	91	17	1.70	2.558	0.268
1990	58	11	1.24	0.540	0.071
1991	52	14	2.15	3.051	0.423
1992	176	29	1.28	1.131	0.085
1993	173	25	2.57	6.212	0.472
1994	197	28	1.52	1.095	0.078
1995	235	27	1.59	1.126	0.073
1996	179	21	1.36	0.755	0.056
1997	103	23	1.23	0.564	0.056
1998	100	17	1.76	1.120	0.112
1999	105	14	1.70	1.475	0.144
2000	60	14	1.95	1.899	0.245
2001	113	12	1.73	1.323	0.124
2002	60	8	2.08	3.110	0.401
2003	43	7	1.60	0.955	0.146
2004	106	14	2.28	1.717	0.167
2005	240	13	1.99	1.390	0.090
2006	105	10	1.76	1.889	0.184
2007	150	15	1.70	1.128	0.092
2008	114	18	1.46	0.970	0.091
2009	89	13	1.74	2.053	0.218
2010	151	19	1.57	0.906	0.074
2011	194	23	2.07	1.830	0.131
2012	231	24	1.79	1.405	0.092
2013	223	20	1.90	1.672	0.112
2014	204	20	1.64	1.139	0.080
2015	160	20	2.54	2.535	0.200
	4040				

Table 2. Number of vessels, number of trips, number of trips that landed Black Grouper, and the ratio of Black Grouper trips to number of trips by year for the headboat trips selected by the Stephens and MacCall logistic regression process.

Year	Number of vessels	Number of trips	Number of trips that landed Black Grouper	Mean number of Black Grouper per trip	Black Grouper trips / number of trips
1986	31	311	100	0.85	0.322
1987	22	206	67	0.94	0.325
1988	18	99	26	0.38	0.263
1989	6	21	14	2.29	0.667
1990	2	3	2	1.00	0.667
1991	19	116	37	0.73	0.319
1992	31	242	84	0.71	0.347
1993	31	183	70	1.61	0.383
1994	32	181	60	0.70	0.331
1995	28	145	46	0.71	0.317
1996	19	84	28	0.49	0.333
1997	26	150	50	0.48	0.333
1998	16	69	18	0.52	0.261
1999	13	50	14	0.62	0.280
2000	15	81	29	0.46	0.358
2001	12	45	25	1.29	0.556
2002	9	35	19	1.23	0.543
2003	8	22	15	2.18	0.682
2004	13	85	38	0.89	0.447
2005	14	173	108	1.53	0.624
2006	15	130	62	1.01	0.477
2007	12	121	74	1.07	0.612
2008	21	199	76	0.70	0.382
2009	17	109	43	0.75	0.394
2010	29	261	85	0.67	0.326
2011	26	309	114	0.92	0.369
2012	26	510	168	0.67	0.329
2013	5	32	26	3.03	0.813
2014	3	28	27	3.00	0.964
2015	2	33	29	4.03	0.879
		4033	1554		

Table 3. Stepwise selection of variables to include in estimating the proportion of positive Black Grouper trips (shaded lines) with a GLM (binomial distribution and logit link). The fields include the explanatory variable, degrees of freedom, deviance, mean deviance, Chi-square degrees of freedom, Chi-square value, probability of the null hypothesis, percent reduction in deviance, whether the model converged, and the cumulative percent reduction in deviance.

Explanatory variable	Degrees of freedom	Deviance	Mean deviance	Chi-square degrees of freedom	Chi-square	Probability of null hypothesis	Percent reduction in deviance	Converged	Cumulative percent reduction in mean deviance
NULL	4032	5376.9	1.334	.	.	.	.	Conv	
hrs	4026	4983.1	1.238	6	393.79	0.000	7.19	Conv	7.19
year	4003	5132.1	1.282	29	244.74	0.000	3.86	Conv	
adj_trip	4031	5243.9	1.301	1	132.96	0.000	2.45	Conv	
area	4031	5263.1	1.306	1	113.78	0.000	2.09	Conv	
angl_cat	4021	5322.4	1.324	11	54.48	0.000	0.74	Conv	
month	4025	5362.4	1.332	7	14.51	0.043	0.10	Conv	
hrs	4026	4983.1	1.238	.	.	.	.	Conv	
hrs year	3997	4901.5	1.226	29	81.56	0.000	0.86	Conv	8.04
hrs area	4025	4972.7	1.235	1	10.38	0.001	0.17	Conv	
hrs month	4019	4969.4	1.236	7	13.64	0.058	0.09	Conv	
hrs adj_trip	4026	4983.1	1.238	0	0.00	.	0.00	Conv	
hrs angl_cat	4015	4971.3	1.238	11	11.84	0.376	-0.03	Conv	
hrs year	3997	4901.5	1.226	.	.	.	.	Conv	
hrs year month	3990	4889.1	1.225	7	12.45	0.087	0.07	Conv	
hrs year area	3996	4899.7	1.226	1	1.87	0.172	0.01	Conv	
hrs year adj_trip	3997	4901.5	1.226	0	0.00	.	0.00	Conv	
hrs year angl_cat	3986	4889.2	1.227	11	12.32	0.340	-0.02	Conv	

Table 4. Stepwise selection of variables to include in estimating the number of Black Grouper landed on positive Black Grouper trips (shaded lines) with a GLM (gamma distribution and log link). The fields include the variable, degrees of freedom, deviance, mean deviance, Chi-square degrees of freedom, Chi-square value, probability of the null hypothesis, percent reduction in deviance, whether the model converged, and the cumulative percent reduction in deviance.

Explanatory variable	Degrees of freedom	Deviance	Mean deviance	Chi-square degrees of freedom	Chi-square	Probability of null hypothesis	Percent reduction in deviance	Converged	Cumulative percent reduction in mean deviance
NULL	1553	1008.8	0.650	.	.	.	.	Conv	
hrs	1547	854.7	0.553	6	280.50	0.000	14.94	Conv	14.94
year	1524	894.4	0.587	29	204.15	0.000	9.66	Conv	
adj_trip	1552	942.2	0.607	1	116.06	0.000	6.55	Conv	
angl_cat	1542	947.1	0.614	11	107.26	0.000	5.45	Conv	
month	1546	963.1	0.623	7	78.78	0.000	4.10	Conv	
area	1552	978.9	0.631	1	51.18	0.000	2.90	Conv	
hrs	1547	854.7	0.553	.	.	.	.	Conv	
hrs year	1518	800.1	0.527	29	110.86	0.000	3.91	Conv	18.854
hrs month	1540	829.7	0.539	7	50.02	0.000	2.12	Conv	
hrs angl_cat	1536	833.2	0.542	11	43.01	0.000	1.56	Conv	
hrs adj_trip	1547	854.7	0.553	0	0.00	.	0.00	Conv	
hrs area	1546	854.7	0.553	1	0.16	0.693	-0.05	Conv	
hrs year	1518	800.1	0.527	.	.	.	.	Conv	
hrs year month	1511	783.4	0.518	7	35.31	0.000	1.33	Conv	20.18
hrs year angl_cat	1507	785.4	0.521	11	31.08	0.001	0.91	Conv	
hrs year area	1517	796.6	0.525	1	7.30	0.007	0.30	Conv	
hrs year adj_trip	1518	800.1	0.527	0	0.00	.	0.00	Conv	

Table 4 continued. Stepwise selection of variables to include in estimating the number of Black Grouper landed on positive Black Grouper trips (shaded lines) with a GLM (gamma distribution and log link). The fields include the variable, degrees of freedom, deviance, mean deviance, Chi-square degrees of freedom, Chi-square value, probability of the null hypothesis, percent reduction in deviance, whether the model converged, and the cumulative percent reduction in deviance.

Explanatory variable	Degrees of freedom	Deviance	Mean deviance	Chi-square degrees of freedom	Chi-square	Probability of null hypothesis	Percent reduction in deviance	Converged	Cumulative percent reduction in mean deviance
hrs year month	1511	783.4	0.518	.	.	.	.	Conv	
hrs year month angl_cat	1500	767.7	0.512	11	33.99	0.000	1.03	Conv	21.21
hrs year month area	1510	780.0	0.517	1	7.34	0.007	0.30	Conv	
hrs year month adj_trip	1511	783.4	0.518	0	0.00	.	0.00	Conv	
hrs year month angl_cat	1500	767.7	0.512	.	.	.	.	Conv	
hrs year month angl_cat area	1499	764.6	0.510	1	6.67	0.010	0.26	Conv	
hrs year month angl_cat adj_trip	1500	767.7	0.512	0	0.00	.	0.00	Conv	

Table 5. Standardized headboat index (catch rates), their coefficient of variation, number of trips, and number of positive trips by year

Year	Index Number per trip	CV	Index Scaled to mean	Number of trips	Number of positive trips
1986	1.61	0.102	1.04	311	100
1987	1.69	0.115	1.09	206	67
1988	1.03	0.177	0.67	99	26
1989	2.08	0.233	1.35	21	14
1990	0.83	2.748	0.53	3	2
1991	1.54	0.151	0.99	116	37
1992	1.63	0.107	1.05	242	84
1993	2.26	0.110	1.47	183	70
1994	1.54	0.120	1.00	181	60
1995	1.60	0.134	1.04	145	46
1996	1.23	0.165	0.80	84	28
1997	1.12	0.128	0.73	150	50
1998	1.29	0.213	0.83	69	18
1999	1.75	0.235	1.13	50	14
2000	1.08	0.160	0.70	81	29
2001	1.44	0.167	0.94	45	25
2002	1.30	0.191	0.84	35	19
2003	2.64	0.208	1.71	22	15
2004	1.31	0.140	0.85	85	38
2005	2.03	0.093	1.31	173	108
2006	1.44	0.111	0.93	130	62
2007	1.51	0.102	0.98	121	74
2008	1.35	0.106	0.87	199	76
2009	1.08	0.163	0.70	109	43
2010	1.41	0.109	0.91	261	85
2011	1.76	0.095	1.14	309	114
2012	1.39	0.086	0.90	510	168
2013	2.00	0.200	1.29	32	26
2014	1.99	0.162	1.29	28	27
2015	2.30	0.183	1.49	33	29
				4033	1554

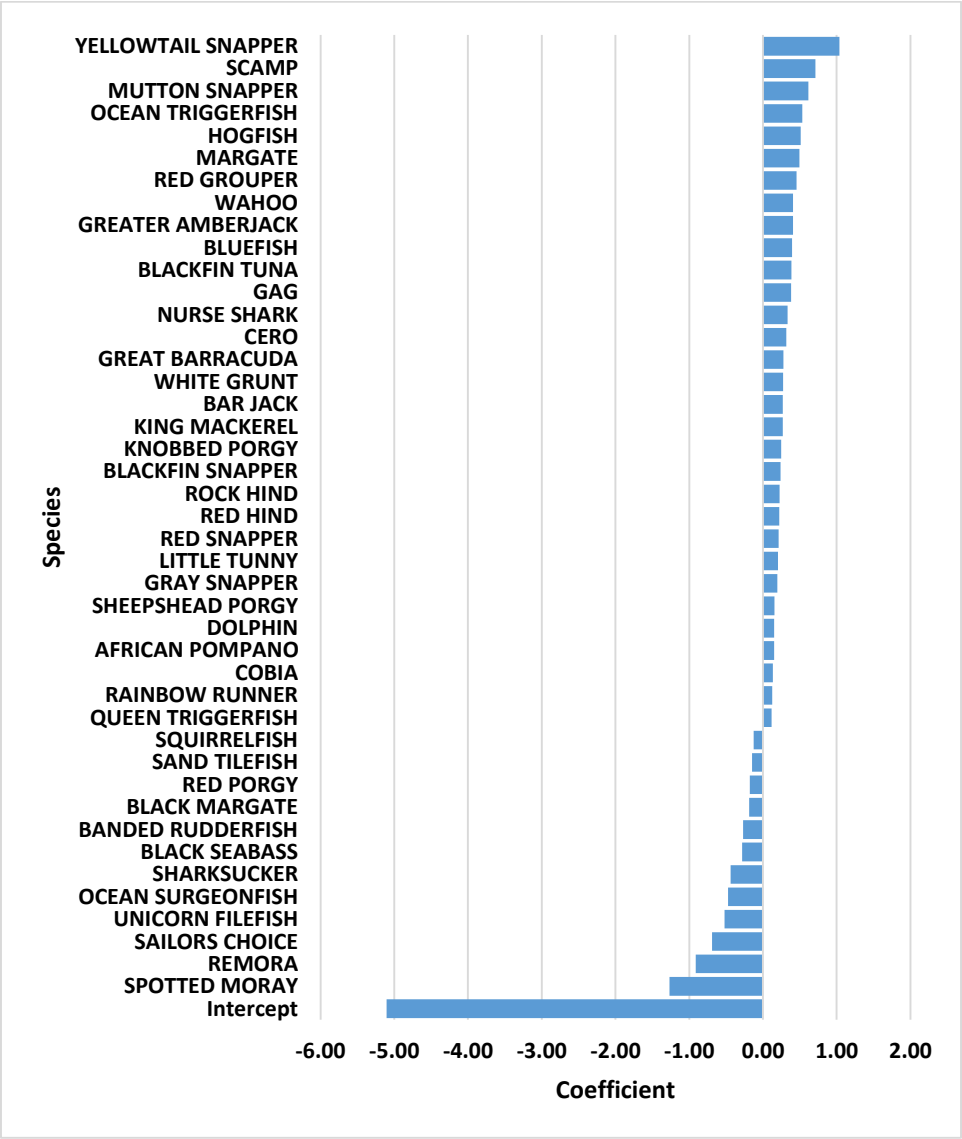


Figure 1. The logistic regression coefficients for the species used to estimate whether catching Black Grouper was likely on each trip.

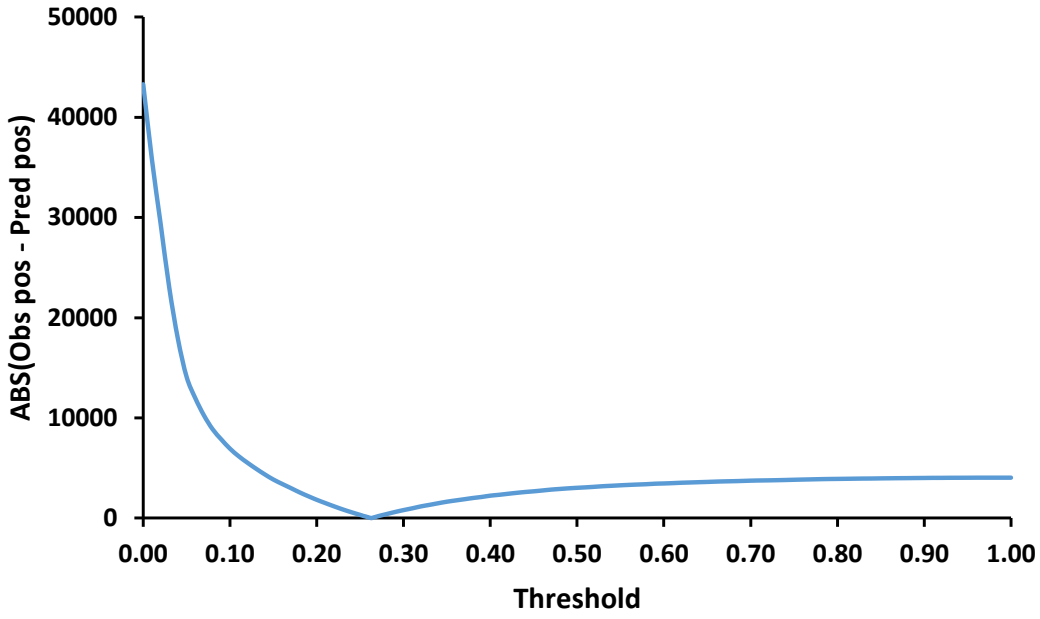
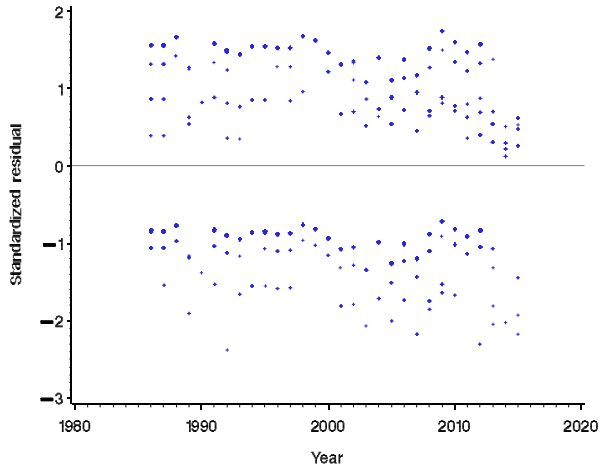
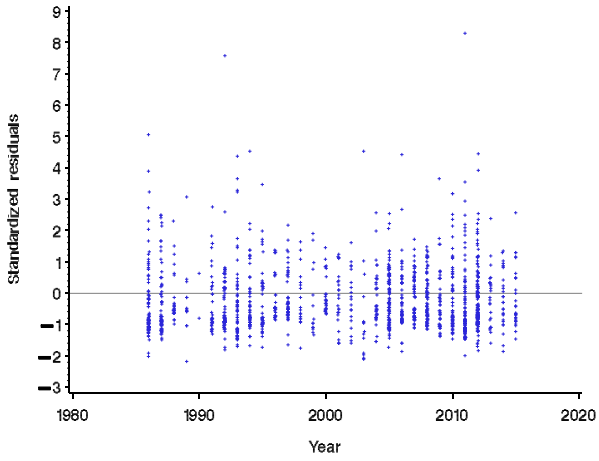


Figure 2. Identifying the threshold value associated with the minimum difference between the observed number of positive trips and the predicted number of positive trips.

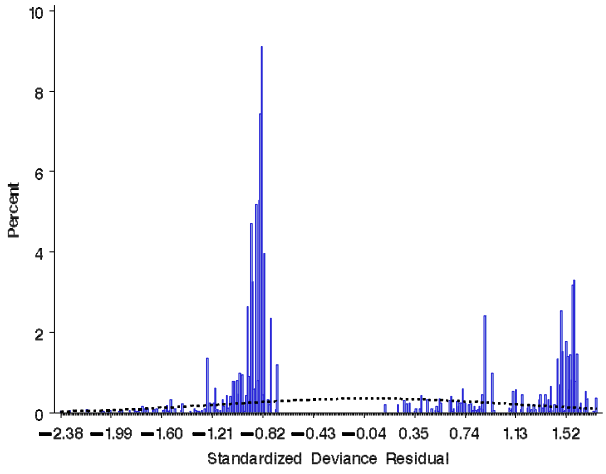
a.



b.



c.



d.

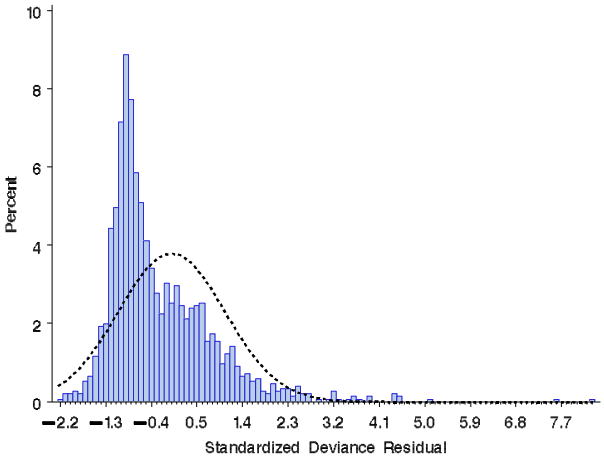
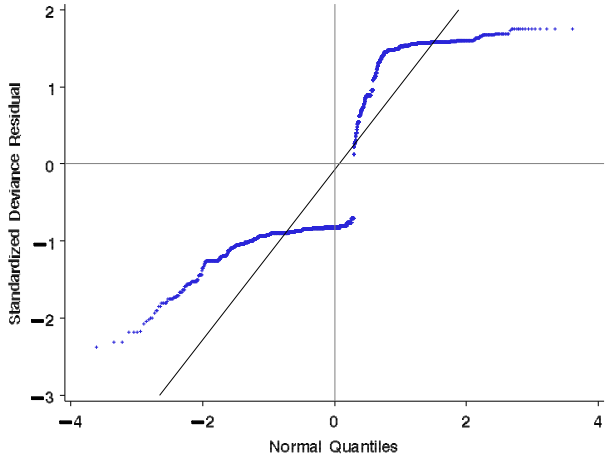


Figure 3. Diagnostic plots for the probability of landing a Black Grouper fit using a binomial distribution, standardized residuals, a and c, and q-q plot, e; and for the number of Black Grouper landed on a trip using a gamma distribution, standardized residuals, b and d, and q-q plot, f.

e.



f.

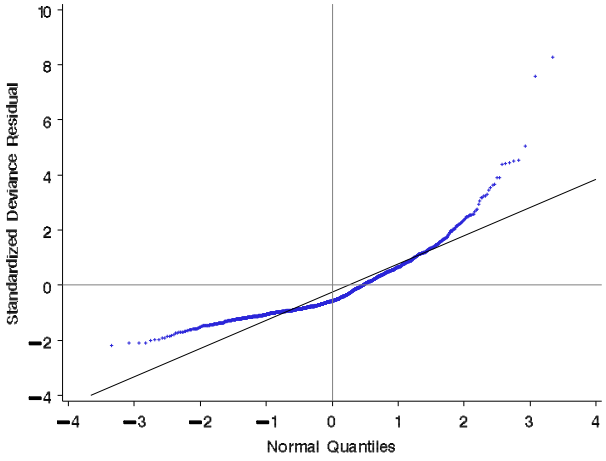


Figure 3 continued. Diagnostic plots for the probability of landing a Black Grouper fit using a binomial distribution, standardized residuals, a and c, and q-q plot, e; and for the number of Black Grouper landed on a trip using a gamma distribution, standardized residuals, b and d, and q-q plot, f.

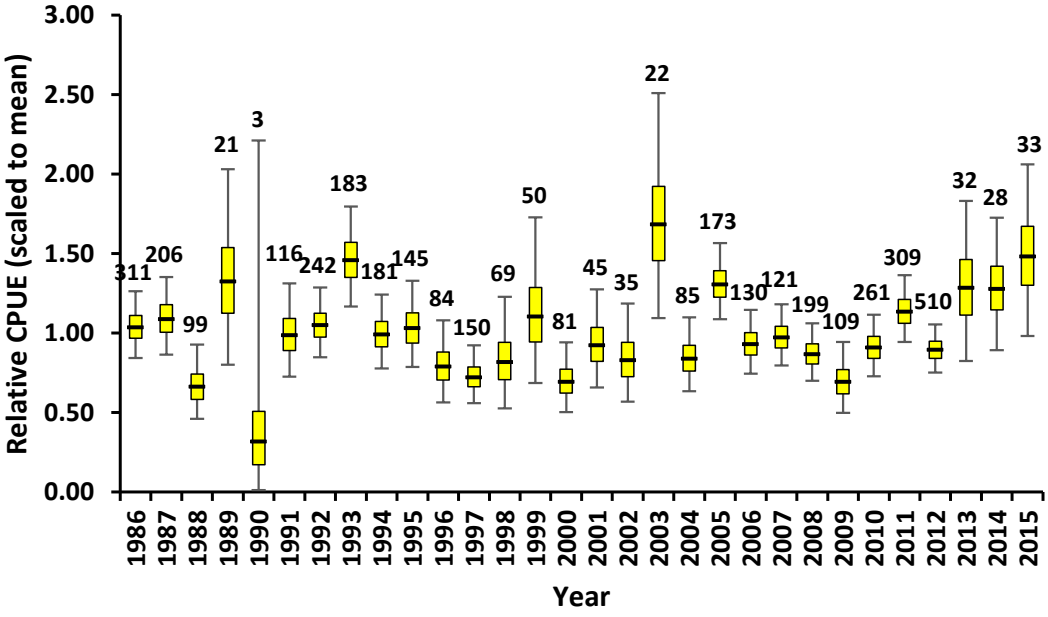


Figure 4. Box plot of the standardized Black Grouper headboat catch rates. The horizontal line is the median estimate; the box is the inter-quartile range, and the vertical line is the 95% confidence interval. The number of trips by year is shown above the confidence interval.

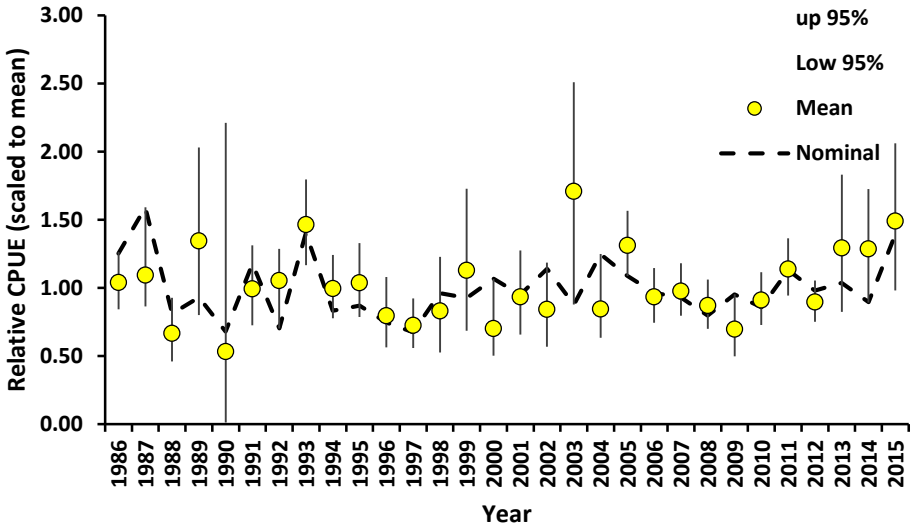


Figure 5. Comparison of standardized catch rates with their confidence intervals and nominal catch rates by year