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Red grouper standardized catch rates from the Marine Recreational Fisheries Statistics Survey for the southeastern U.S. Atlantic Ocean, 1991-2008

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U.S. Atlantic Ocean recreational catches of red grouper, *Epinephelus morio*, occur most commonly off southern Florida and North Carolina coasts in the private/rental boat and charterboat modes. The Marine Recreational Fisheries Statistics Survey (MRFSS) is a fishery-dependent survey where total catch including discards is reported in angler intercepts and effort is estimated from telephones surveys. Total catch rates (i.e., catch per unit effort, CPUE) can indicate changes in relative abundance. In 1991, MRFSS made several improvements to the survey including linking ancillary intercepts from the same fishing trip together and recording the total number of anglers in the party. Additionally, a 20-inch total length minimum size was mandated for red grouper in 1990. Therefore, the data for this analysis was constrained to MRFSS intercepts from 1991-2008 in the private/rental boat and charterboat modes from North Carolina through the Florida Keys (Figure 1). We attempted to calculate two separate indices, north and south of Cape Canaveral, but data were not sufficient for convergence in the northern region. Therefore, we generated a single index that included region as a potential variable.

There were 91,018 MRFSS intercepts in the charterboat and private/rental boat modes from nearshore (state waters) and offshore waters (federal waters), and 48 species including red grouper occurred on at least 1% of those intercepts. In this analysis, those additional intercepts from the same fishing trip that caught fish but were unavailable to the creel sampler were linked back to the main intercept for the party.

Over the 18 years from 1991 through 2008, there were 2,172 intercepts that caught red grouper in the study area (Table 1, Figure 2). However, there were trips that could have caught red grouper, but didn't. To identify that effort and include it in the catch rate standardization process, Stephens and MacCall (2004) logistic regressions (S&M) were employed. The rationale of S&M is to identify a homogeneous group of intercepts that are believed to reflect the abundance of the target species. The S&M method uses a logistic regression of presence or absence by species on each intercept to predict whether the target species (red grouper) could be caught on the trip. Following Stephens and

MacCall's example, we omitted species that occurred on less than 1% of the total number of intercepts.

For the S&M method, the intercept data were rearranged to one record per intercept with binomial (presence or absence) information for each of the 48 species. The response variable in the logistic regression was the presence (1) or absence (0) of red grouper on each intercept and the predictor variables in the full model were the presence or absence of the other 47 species. There were 29 species (Table 2, Figure 3) whose regression coefficients were significant at the $\alpha = 0.05$ level and those species were used in the final, reduced model.

Potential thresholds (estimated probability of catching red grouper) for choosing whether to include an intercept in the catch rate analysis ranged from 0.01 to 0.99 and the critical value was based on the minimum absolute difference between observed number of intercepts with red grouper and the predicted number of intercepts. The smallest absolute difference occurred with a threshold of 0.155 (Figure 4). There were 2,195 intercepts that exceeded the 0.155 threshold.

Once the MRFSS intercepts for calculating the catch rates were selected, the total number of red grouper caught was calculated for each selected intercept and annual catch rates were estimated with generalized linear models (GLM). We applied an approach based on Lo et al. (1992) by dividing the data into two datasets: 1) red grouper presence or absence data (2,195 intercepts) and fit to a GLM with a binomial distribution with a logit link and 2) the total catch of red grouper on positive intercepts (543 intercepts) were fit to a GLM with a gamma distribution with a log link. Potential explanatory variables were year (1991-2008), wave (two-month time period), mode (charterboat or private/rental boat), area (nearshore or offshore), region (North Carolina through Georgia; Nassau County through Flagler County, Florida: Volusia County through Dade County, Florida; and Monroe County, Florida), hours fished (0, 2, 4, 6, 8, 10, 12+ hr), and the number of anglers on the trip (1, 2, 3, 4, 5, 6, 8, 10, 12+). Potential variables were evaluated for inclusion in the GLM through a step-wise process. For each step-wise level, provided that the variable with the lowest Akaike Information Criterion (AIC) value was also significant at the $\alpha = 0.05$ level (from twice the change in log-likelihood), that variable was added to the model for use in the calculations in the next step (Table 3a and 3b).

The quantile plot and the distribution of standardized residuals from the GLM for the proportion of positive intercepts using a binomial distribution with a logit link seem reasonable (Figure 5); however, there were some departures from the expected at the tails. The GLM explained 3.8% of the deviance with year explaining 2.2% of the deviance (Table 3a), and wave, region and number of anglers explaining the rest. The model for the total number of red grouper caught per intercept on positive intercepts using a gamma distribution with a log link explained 8.6% of the deviance with most of the deviance explained by number of anglers (3.1%), year (3.0%), and the rest by mode and hours fished (Table 3b). The annual mean catch per intercept values (Table 1, Stephens and MacCall columns) were calculated with a Monte Carlo method based on the number of intercepts by two-month wave, region, and number of anglers per year to

determine the probability of a non-zero intercept multiplied by the mean number of red grouper caught per angler. Random variation was added to each outcome by multiplying the standard error of the proportion positive by a random, normal deviate and by multiplying the standard error of the number per intercept by a different random, deviate. After the random deviates were added to the terms, the terms were back-transformed to their original scales and multiplied together. This process was repeated for each of the 2,195 intercepts and the index was the mean of the outcomes by year (Figure 6).

The S&M standardization method appears to add noise to the relative abundance index data (Figure 7), probably due to the subsetting of an already sparse data set. However, a trend is more apparent in the standardized relative CPUE index than in the nominal index.

Literature Cited

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.

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

Table 1. Nominal and standardized total catch rates of red grouper from charterboat and private/rental boat MRFSS modes from nearshore and offshore waters from North Carolina through the Florida Keys using intercepts selected with the Stephens and MacCall logistic regressions. The N is the number of intercepts included in the analysis where red grouper were caught.

Nominal					Stephens and MacCall				
year	N	Mean	CV	Scaled to mean	year	N	Mean	CV	Scaled to mean
1991	64	4.36	0.15	0.97	1991	8	0.34	0.51	0.25
1992	92	4.64	0.12	1.04	1992	14	0.36	0.36	0.26
1993	77	4.03	0.16	0.90	1993	9	0.98	0.84	0.72
1994	77	4.78	0.14	1.07	1994	19	1.23	0.37	0.90
1995	58	5.29	0.23	1.18	1995	7	0.36	0.59	0.26
1996	74	4.81	0.13	1.07	1996	20	1.52	0.35	1.11
1997	60	5.63	0.18	1.26	1997	11	1.07	0.61	0.78
1998	70	4.20	0.14	0.94	1998	13	1.42	0.50	1.04
1999	90	4.12	0.20	0.92	1999	21	0.76	0.32	0.56
2000	108	5.23	0.15	1.17	2000	25	0.87	0.33	0.64
2001	138	3.04	0.13	0.68	2001	42	1.02	0.26	0.75
2002	201	4.80	0.11	1.07	2002	53	2.23	0.25	1.63
2003	185	4.02	0.10	0.90	2003	54	1.51	0.26	1.10
2004	194	5.81	0.10	1.30	2004	56	1.66	0.27	1.22
2005	159	3.81	0.10	0.85	2005	68	1.76	0.22	1.29
2006	187	4.77	0.15	1.06	2006	47	0.92	0.27	0.67
2007	181	3.60	0.12	0.80	2007	26	0.57	0.39	0.42
2008	180	4.52	0.09	1.01	2008	48	1.79	0.28	1.31

Table 2. Species names and codes with significant regression coefficients ($\alpha = 0.05$) to predict whether red grouper were caught on MRFSS intercepts for charterboat and private/rental boat MRFSS modes from nearshore and offshore waters from southern Florida.

NODC Code	Scientific Name	Common Name	Coefficient	Error
		Intercept	-3.9695	0.0372
8835020501	Mycteroperca microlepis	GROUPER, GAG	1.2889	0.0765
8835400102	Haemulon plumieri	GRUNT, WHITE	1.2327	0.0664
8835020502	Mycteroperca bonaci	GROUPER, BLACK	1.1852	0.0882
8835360103	Lutjanus analis	SNAPPER, MUTTON	1.0144	0.0663
8835360401	Ocyurus chrysurus	SNAPPER, YELLOWTAIL	0.8849	0.0609
8860020201	Balistes capriscus	TRIGGERFISH, GRAY	0.6859	0.0758
8835360112	Lutjanus synagris	SNAPPER, LANE	0.6182	0.0925
8835360102	Lutjanus griseus	SNAPPER, GRAY	0.5914	0.0678
8850030503	Scomberomorus regalis	CERO	0.4622	0.1092
8835360107	Lutjanus campechanus	SNAPPER, RED	0.4602	0.1073
8835360501	Rhomboplites aurorubens	SNAPPER, VERMILION	0.3567	0.098
8850030102	Euthynnus alletteratus	TUNNY, LITTLE	-0.2466	0.0752
8835290101	Coryphaena hippurus	DOLPHIN	-0.466	0.0673
8857030300	Carcharhinidae	SHARKS, REQUIEM	-0.4756	0.2273
8835430201	Lagodon rhomboides	PINFISH	-0.5972	0.1839
8850030601	Acanthocybium solandri	WAHOO	-0.6026	0.1839
8835400201	Orthopristis chrysoptera	PIGFISH	-0.757	0.3612
8850030502	Scomberomorus maculatus	MACKEREL, SPANISH	-0.7967	0.1206
8738020201	Megalops atlanticus	TARPON	-0.8486	0.3391
8835430301	Archosargus probatocephalus	SHEEPSHEAD	-0.9466	0.3098
8835250101	Pomatomus saltatrix	BLUEFISH	-1.2057	0.198
8857030301	Paralichthys dentatus	FLOUNDER, SUMMER	-1.4209	0.7127
8835440102	Cynoscion nebulosus	SEATROUT, SPOTTED	-1.6173	0.3867
8835380101	Lobotes surinamensis	TRIPLETAIL	-1.6875	0.5796
8835440901	Sciaenops ocellatus	DRUM, RED	-1.9368	0.5027
8850030403	Thunnus albacares	TUNA, YELLOWFIN	-2.4691	0.4503
8857030301	Thunnus	TUNA	-2.9012	1.0003
8835440702	Micropogonias undulatus	CROAKER, ATLANTIC	-2.9293	1.0017
8738020201	Paralichthys	FLOUNDER	-3.227	1.0013

Table 3a. Stepwise selection of variables to include in estimating the proportion of positive MRFSS intercepts for red grouper (shaded lines) with a GLM (binomial distribution and logit link) selected with Stephens and MacCall logistic regression based on lowest AIC values. The fields include the variables, the degrees of freedom for that variable (df), the deviance of the model with those variables, the mean deviance (deviance/df), the change in mean deviance (Δ mean dev), percent reduction in mean deviance (% mean dev), cumulative reduction in mean deviance, log likelihood, the change in log likelihood from previous run, minus two times the change in log-likelihood, chi-square value, the Chi-square degrees of freedom, the probability of the null hypothesis (Prob Ho), and the Akaike Information Criterion (AIC).

Variables		df	Deviance	Mean dev	Δ mean dev	% expl	Cum %	log like	Δ log like	Chi sq	df	Prob Ho	AIC
Null	Deviance	2194	2451.4764	1.1174				-1225.7382			1		2453.4764
Year	Deviance	2177	2380.1675	1.0933	0.0241	2.2%	2.2%	-1190.0838	-35.6544	71.31	17	1.282E-08	2416.1676
Wave	Deviance	2189	2419.7518	1.1054	0.012	1.1%		-1209.8759	-15.8623	31.72	5	6.736E-06	2431.7518
Area	Deviance	2193	2450.0254	1.1172	0.0002	0.0%		-1225.0127	-0.7255	1.45	1	0.2283677	2454.0254
Mode_fx	Deviance	2193	2442.6328	1.1138	0.0036	0.3%		-1221.3164	-4.4218	8.84	1	0.0029412	2446.6328
Region	Deviance	2191	2443.6052	1.1153	0.0021	0.2%		-1221.8026	-3.9356	7.87	3	0.04875	2451.6052
Hr fished	Deviance	2188	2439.6921	1.115	0.0024	0.2%		-1219.846	-5.8922	11.78	6	0.0669551	2453.692
Num anglers	Deviance	2186	2434.5366	1.1137	0.0037	0.3%		-1217.2683	-8.4699	16.94	8	0.0307421	2452.5366
With year													
Wave	Deviance	2172	2350.6239	1.0822	0.0111	1.0%	3.2%	-1175.3119	-14.7719	29.54	5	1.813E-05	2396.6238
Area	Deviance	2176	2379.7677	1.0936	-0.0003	0.0%		-1189.8839	-0.1999	0.40	1	0.5271926	2417.7678
Mode_fx	Deviance	2176	2378.3392	1.093	0.0003	0.0%		-1189.1696	-0.9142	1.83	1	0.1763167	2416.3392
Region	Deviance	2174	2366.2847	1.0884	0.0049	0.4%		-1183.1424	-6.9414	13.88	3	0.0030691	2408.2848
Hr fished	Deviance	2171	2368.1011	1.0908	0.0025	0.2%		-1184.0505	-6.0333	12.07	6	0.0604994	2416.101
Num anglers	Deviance	2169	2365.1808	1.0904	0.0029	0.3%		-1182.5904	-7.4934	14.99	8	0.0594026	2417.1808

With year and wave													
Area	Deviance	2171	2349.8185	1.0824	-0.0002	0.0%		-1174.9092	-0.4027	0.81	1	0.3694837	2397.8184
Mode_fx	Deviance	2171	2348.6185	1.0818	0.0004	0.0%		-1174.3092	-1.0027	2.01	1	0.15674	2396.6184
Region	Deviance	2169	2340.1496	1.0789	0.0033	0.3%	3.4%	-1170.0748	-5.2371	10.47	3	0.0149369	2392.1496
Hr fished	Deviance	2166	2339.2064	1.08	0.0022	0.2%		-1169.6032	-5.7087	11.42	6	0.0763016	2397.2064
Num anglers	Deviance	2164	2335.0378	1.079	0.0032	0.3%		-1167.5189	-7.793	15.59	8	0.0487039	2397.0378
With year, wave, and region													
Area	Deviance	2168	2340.1017	1.0794	-0.0005	0.0%		-1170.0508	-0.024	0.05	1	0.8265807	2394.1016
Mode_fx	Deviance	2168	2340.0676	1.0794	-0.0005	0.0%		-1170.0338	-0.041	0.08	1	0.7746051	2394.0676
Hr fished	Deviance	2163	2331.2194	1.0778	0.0011	0.1%		-1165.6097	-4.4651	8.93	6	0.1775418	2395.2194
Num anglers	Deviance	2161	2323.2756	1.0751	0.0038	0.3%	3.8%	-1161.6378	-8.437	16.87	8	0.0314482	2391.2756
With year, wave, region, and num_angler													
Area	Deviance	2160	2323.2079	1.0756	-0.0005	0.0%		-1161.604	-0.0338	0.07	1	0.7948638	2393.208
Mode_fx	Deviance	2160	2322.4986	1.0752	-1E-04	0.0%		-1161.2493	-0.3885	0.78	1	0.3780602	2392.4986
Hr fished	Deviance	2155	2311.2002	1.0725	0.0026	0.2%		-1155.6001	-6.0377	12.08	6	0.0603077	2391.2002

Table 3b. Stepwise selection of variables to include in estimating the total catch of red grouper on positive MRFSS intercepts for red grouper (shaded lines) with a GLM (gamma distribution and log link) selected with Stephens and MacCall logistic regression based on lowest AIC values. The fields include the variables, the degrees of freedom for that variable (df), the deviance of the model with those variables, the mean deviance (deviance/df), the change in mean deviance (Δ mean dev), percent reduction in mean deviance (% mean dev), cumulative reduction in mean deviance, log likelihood, the change in log likelihood from previous run, minus two times the change in log-likelihood, chi-square value, the Chi-square degrees of freedom, the probability of the null hypothesis (Prob Ho), and the Akaike Information Criterion (AIC).

Variables		df	Deviance	Mean dev	Δ mean dev	% expl	Cum %	log like	Δ log like	Chi sq	df	Prob Ho	AIC
Null	Deviance	537	676.2047	1.2592				-1387.0116			2		2778.0232
Year	Deviance	520	632.897	1.2171	0.0421	3.3%		-1366.3435	-20.6681	41.34	17	0.000835607	2770.687
Wave	Deviance	532	655.8203	1.2327	0.0265	2.1%		-1377.4353	-9.5763	19.15	5	0.001800296	2768.8706
Area	Deviance	536	675.7594	1.2607	-0.0015	-0.1%		-1386.8052	-0.2064	0.41	1	0.520551747	2779.6104
Mode_fx	Deviance	536	674.4947	1.2584	0.0008	0.1%		-1386.2182	-0.7934	1.59	1	0.207784039	2778.4364
Region	Deviance	534	672.2152	1.2588	0.0004	0.0%		-1385.1578	-1.8538	3.71	3	0.294818234	2780.3156
Hr fished	Deviance	531	666.1105	1.2544	0.0048	0.4%		-1382.3021	-4.7095	9.42	6	0.151348671	2780.6042
Num anglers	Deviance	529	645.3887	1.22	0.0392	3.1%	3.1%	-1372.4314	-14.5802	29.16	8	0.000297186	2764.8628
With num_anglers													
Year	Deviance	512	607.9763	1.1875	0.0325	2.6%		-1353.87	-18.5614	37.12	17	0.003238566	2761.74
Wave	Deviance	524	631.1711	1.2045	0.0155	1.2%		-1365.4939	-6.9375	13.88	5	0.016423235	2760.9878
Area	Deviance	528	644.3373	1.2203	-0.0003	0.0%		-1371.9231	-0.5083	1.02	1	0.313327127	2765.8462
Mode_fx	Deviance	528	633.182	1.1992	0.0208	1.7%	4.8%	-1366.4836	-5.9478	11.90	1	0.000562667	2754.9672
Region	Deviance	526	644.092	1.2245	-0.0045	-0.4%		-1371.8044	-0.627	1.25	3	0.740084108	2769.6088
Hr fished	Deviance	523	640.0334	1.2238	-0.0038	-0.3%		-1369.8345	-2.5969	5.19	6	0.51920811	2771.669

With num_angl and mode_fx													
Year	Deviance	511	593.3213	1.1611	0.0381	3.0%	7.8%	-1346.3193	-20.1643	40.33	17	0.001162938	2748.6386
Wave	Deviance	523	620.2888	1.186	0.0132	1.0%		-1360.0888	-6.3948	12.79	5	0.025432279	2752.1776
Area	Deviance	527	633.1718	1.2015	-0.0023	-0.2%		-1366.4786	-0.005	0.01	1	0.920344325	2756.9572
Region	Deviance	525	628.6094	1.1974	0.0018	0.1%		-1364.2291	-2.2545	4.51	3	0.211488892	2756.4582
Hr fished	Deviance	522	628.3785	1.2038	-0.0046	-0.4%		-1364.1149	-2.3687	4.74	6	0.57790733	2762.2298
With num_angl, mode_fx, and year													
Wave	Deviance	506	586.0397	1.1582	0.0029	0.2%		-1342.5051	-3.8142	7.63	5	0.177939398	2751.0102
Area	Deviance	510	593.2328	1.1632	-0.0021	-0.2%		-1346.2731	-0.0462	0.09	1	0.761147941	2750.5462
Region	Deviance	508	592.5829	1.1665	-0.0054	-0.4%		-1345.9344	-0.3849	0.77	3	0.856675989	2753.8688
Hr fished	Deviance	505	581.0417	1.1506	0.0105	0.8%	8.6%	-1339.8624	-6.4569	12.91	6	0.044425416	2747.7248
With num_angl, mode_fx, year, and hr_fished													
Wave	Deviance	500	573.6803	1.1474	0.0032	0.3%		-1335.9327	-3.9297	7.86	5	0.164156505	2749.8654
Area	Deviance	504	580.6219	1.152	-0.0014	-0.1%		-1339.6395	-0.2229	0.45	1	0.504336246	2749.279
Region	Deviance	502	579.8717	1.1551	-0.0045	-0.4%		-1339.2408	-0.6216	1.24	3	0.742662891	2752.4816

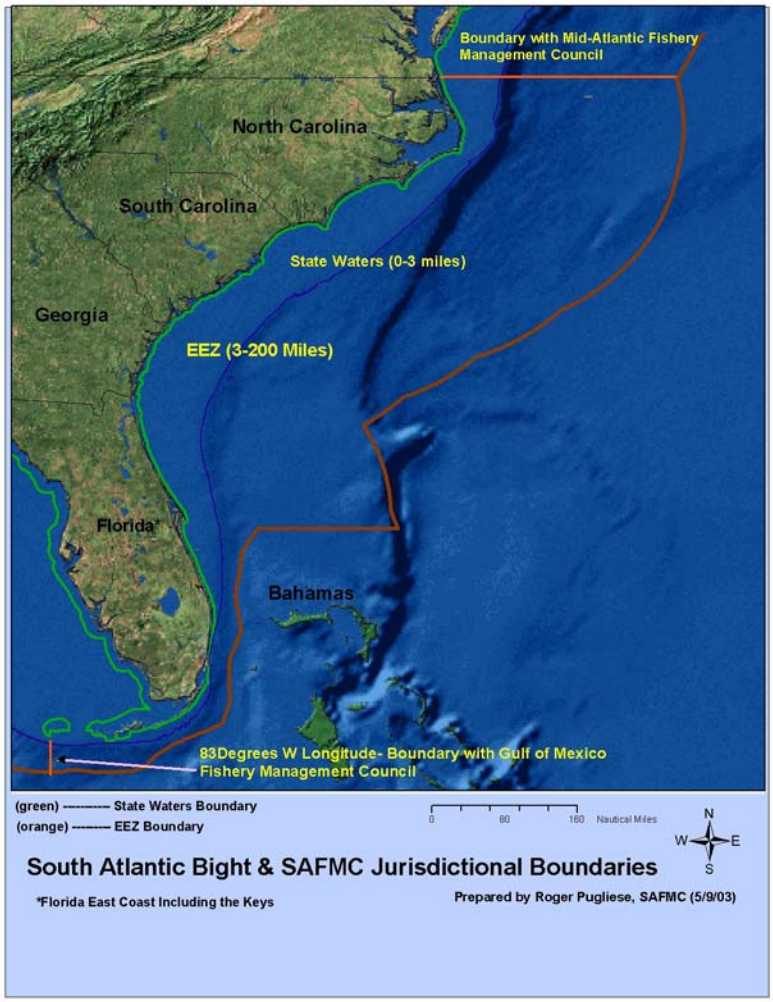

Figure 1. A map of the study area: North Carolina through the Florida Keys.

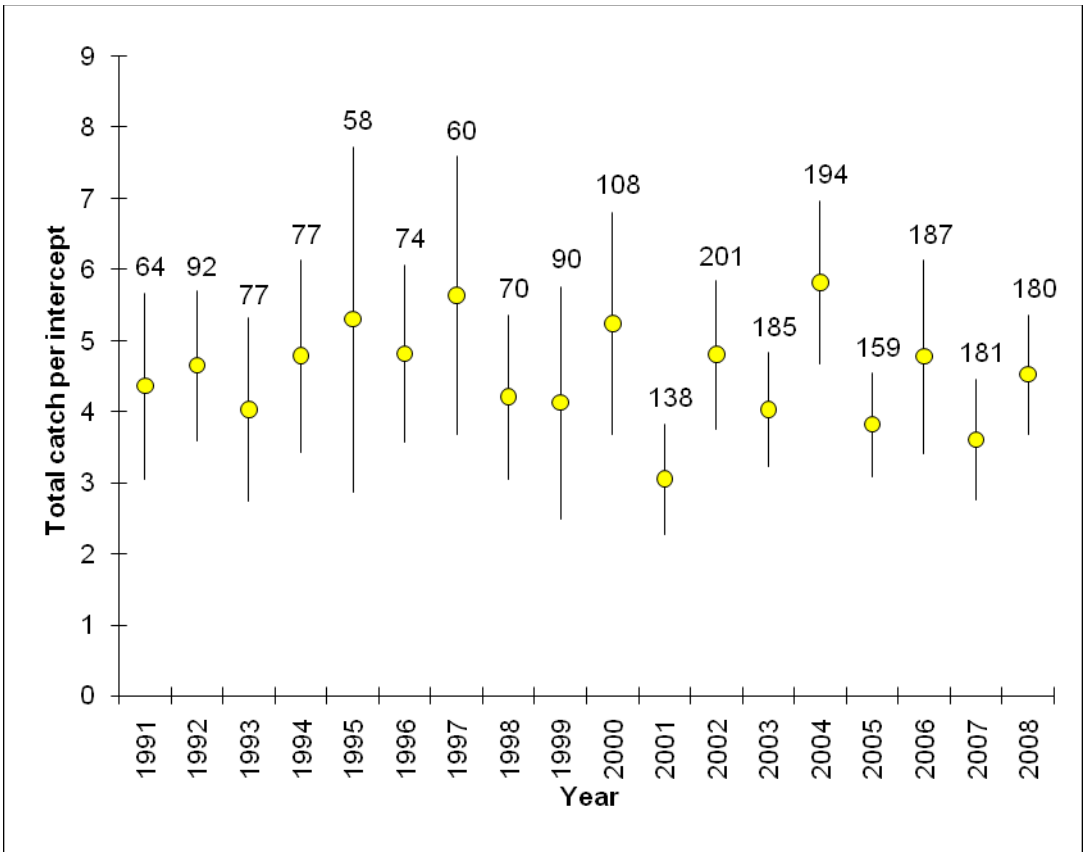

Figure 2. Nominal catch rate of red grouper by year from North Carolina to southern Florida. The vertical lines are the 95% confidence interval and the circle is the mean. The numbers above the figures are the number of intercepts in the private/rental and charterboat modes per year.

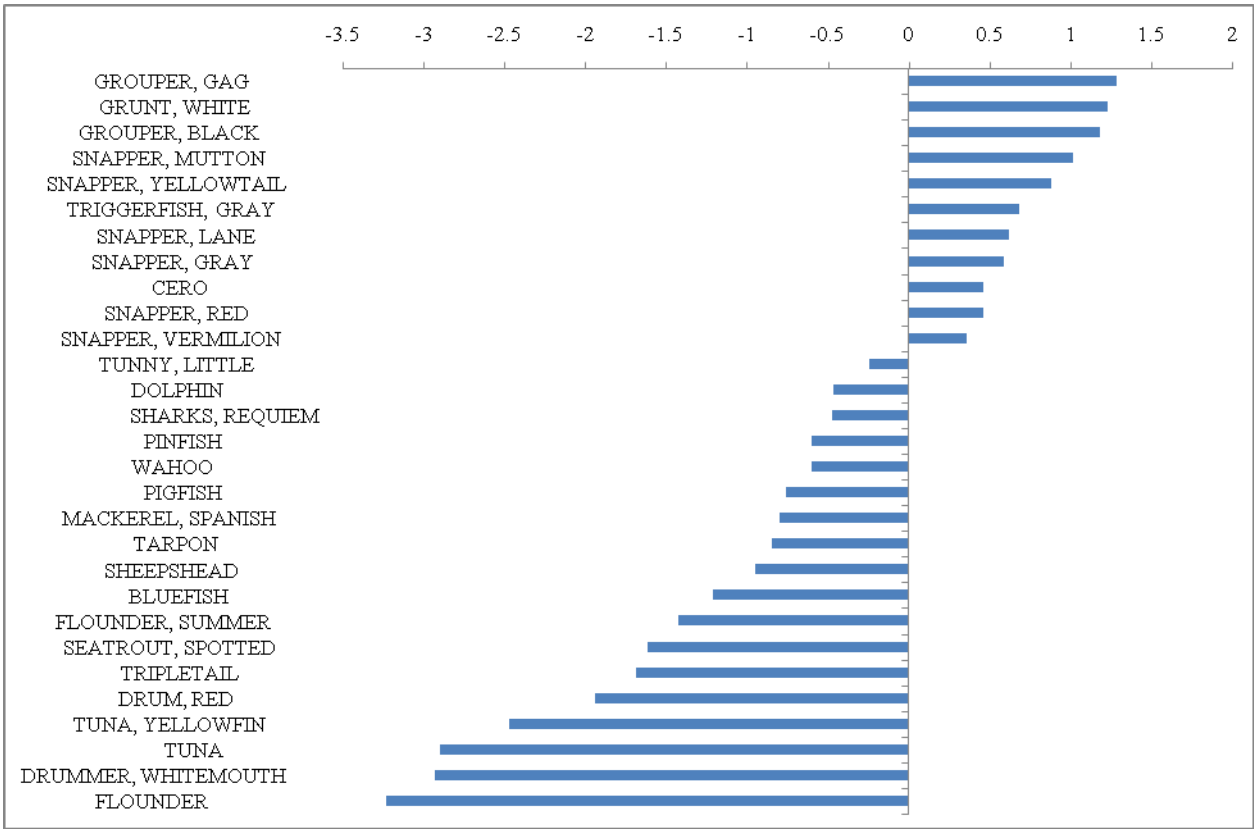

Figure 3. Species with significant logistic regression coefficients at the $\alpha = 0.05$ level for determining whether a MRFSS intercept should be selected for calculating annual total catch rates using the Stephens and MacCall method.

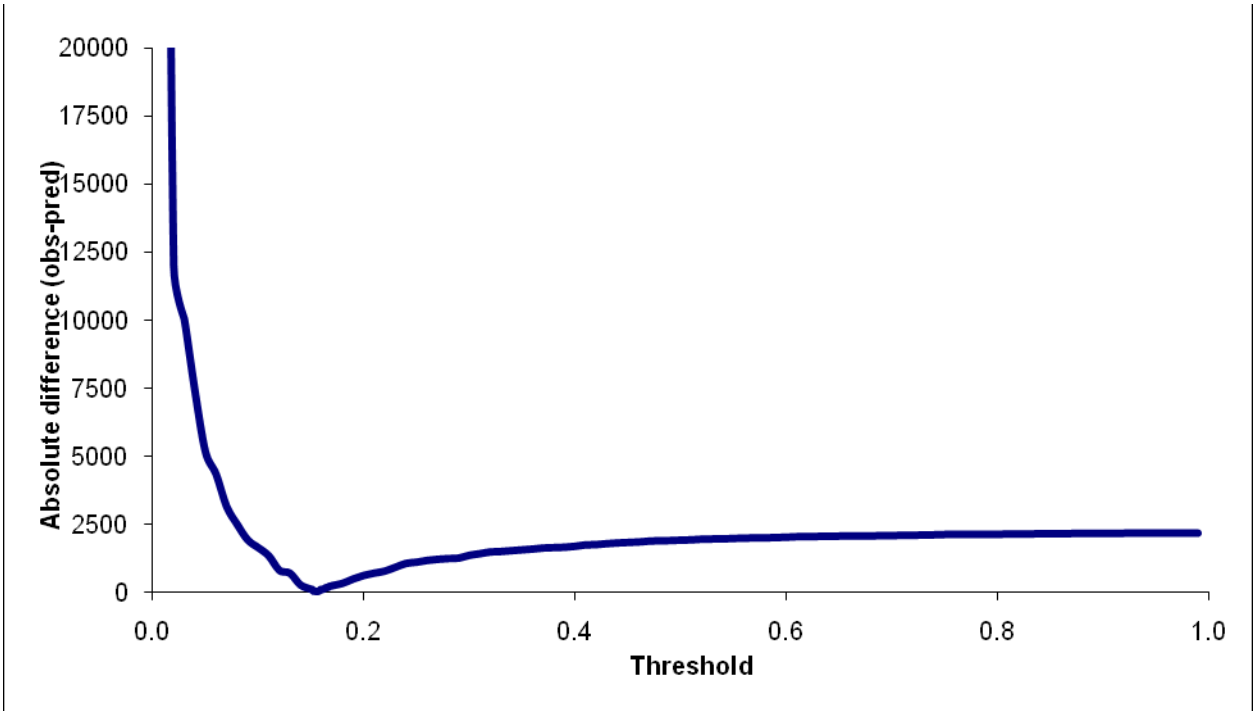

Figure 4. Absolute difference between the numbers of observed and predicted intercepts with red grouper from the logistic regression over a range of threshold values.

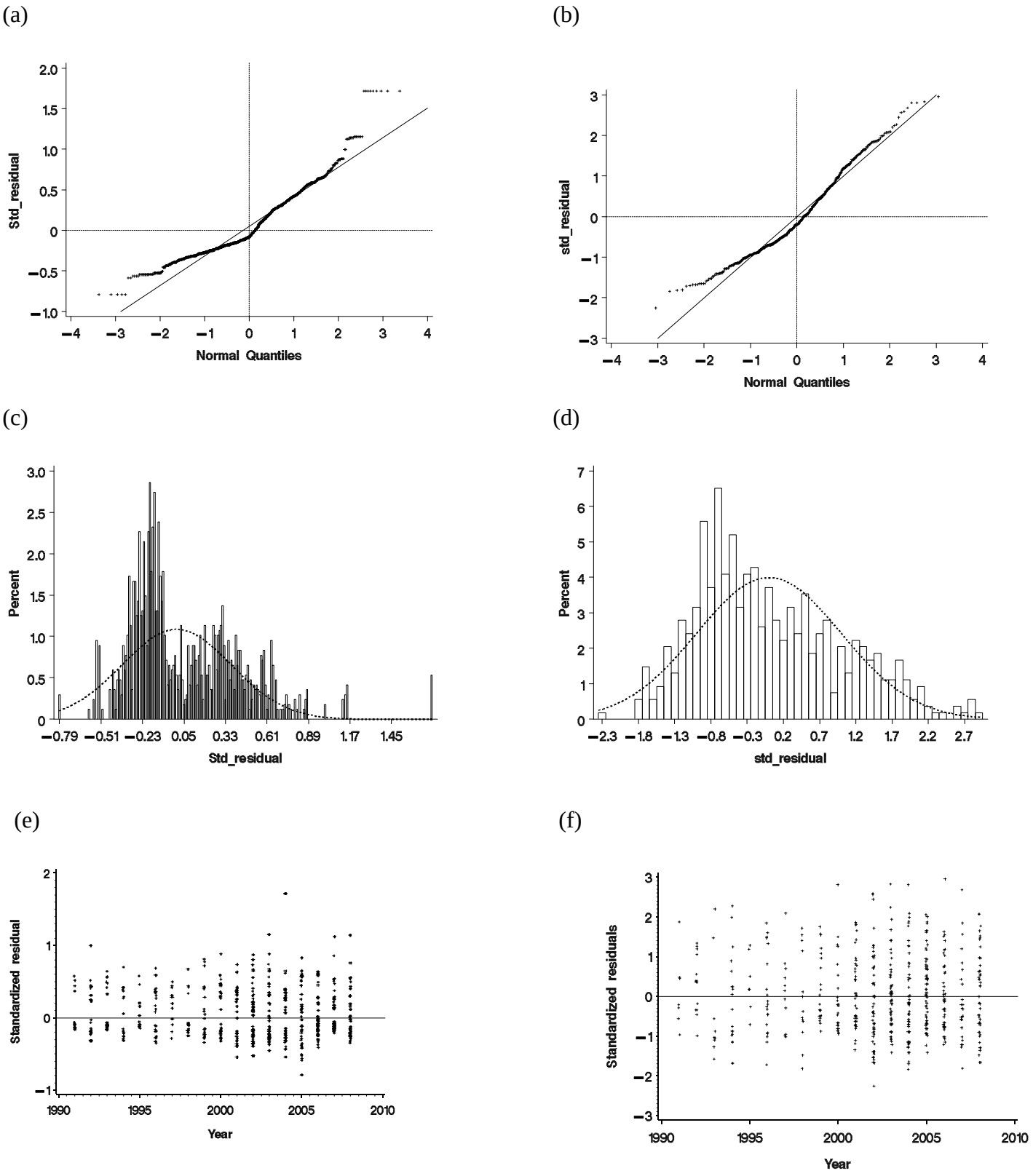

Figure 5. Quantiles plot (a), distribution (c), and a plot of standardized residuals by year (e) for the proportion of positive catches of red grouper from the generalized linear model (GLM) with a binomial distribution and a logit link, and quantiles plot (b), distribution (d), and plot of standardized residuals by year (f) for the number of red grouper positive intercepts from the GLM with a gamma distribution and a log link for the intercepts identified with the Stephens and MacCall regression.

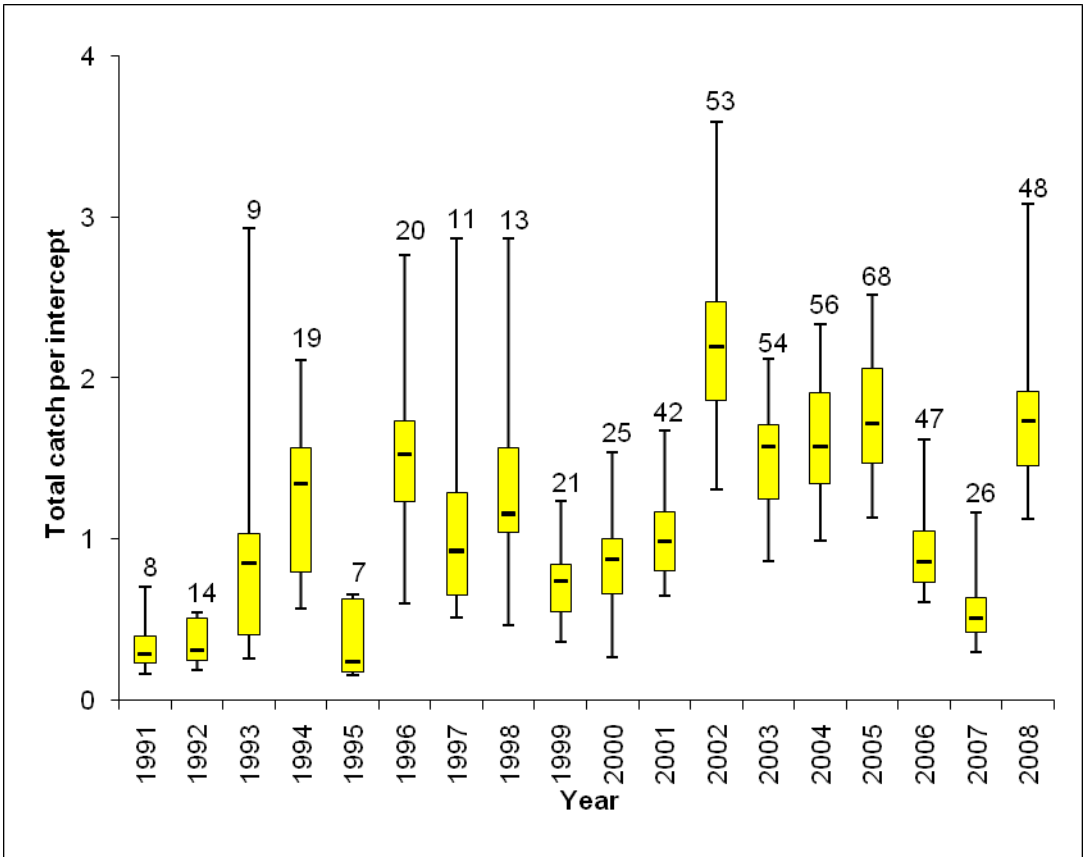

Figure 6. Standardized annual total catch of red grouper per angler hour per intercept with intercepts selected by Stephens and MacCall's logistic regression. The vertical lines are the 95% confidence interval, the box is the inter-quartile range, the horizontal line is the median of the outcomes and the number above the lines are the number of intercepts that caught red grouper for each year.

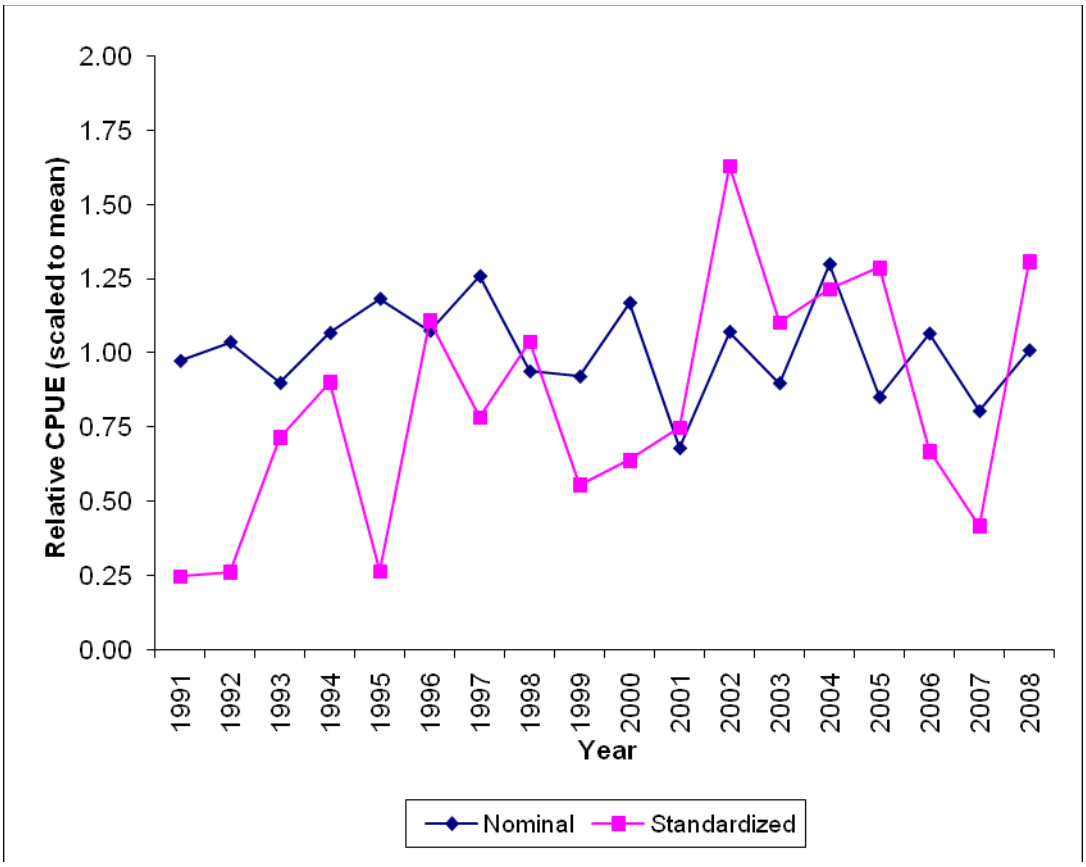

Figure 7. Comparison of the nominal catch rates to the standardized catch rates calculated with intercepts selected by the Stephens and MacCall regression.