A fishery independent index for red grouper, *Epinephelus morio*, from Florida Fish and Wildlife Research Institute's visual survey in the Florida Keys, 1999-2007

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The description of the Florida Fish and Wildlife Conservation Commission (FWC) visual census and the calculations of the catch rate index are in Muller and Acosta (2009, SEDAR19-DW-02). Briefly, the Florida Keys National Marine Sanctuary (FKNMS) was divided into 6 zones (Figure A-1) from Key Largo to the Dry Tortugas and the four zones from Key Largo to Key West are sampled monthly from April through October with stationary point counts. A habitat-based, random-stratified site selection procedure, based upon the "Benthic Habitats of the Florida Keys" GIS system, was used to select 39 sample sites each month. A stationary diver records the number of individuals for each of the target species that are observed within an imaginary five-meter radius cylinder and assigns fish to length intervals. On each dive, the two divers conduct two point-counts that are at least 15 m apart. Because the location of the point-counts may occur in different habitats, numbers of fish were pooled by dive and bottom habitat relief category (high, medium, low).

The FWC visual survey index (VS) used the point-counts from dives conducted from 1999 through 2007. There were no samples taken in 2005 and in 2008, the sampling protocol was changed to the same protocol as used in the NMFS-UM Reef Fish Visual Census (SEDAR19-DW-10,11). There were a total of 2,531 unique dive/habitat combinations and red grouper were observed on 511 of those dive/habitats. The annual nominal point-counts, number per dive/habitat, are shown in Table A-1. We did not convert the number observed to density because the conversion factor is a constant (1.27) and does not affect the trend.

We used an analytical technique to account for dives which could have observed red grouper but did not ("total effort"). The dive/habitats were selected through a logistical regression technique (Stephens and MacCall 2004) that used the presence or absence of other species seen to estimate the probability that dives could have seen red grouper on the dive with that bottom habitat relief. Dive/habitats were selected for calculating the index if the dive/habitat's probability exceeded the threshold as determined by the minimum absolute difference between the observed number of dives and the predicted number. Over the course of the survey, sixty species were observed but only 45 species were seen on at least 1% of the dives. The reduced logistic regression model used 12 species of fish (those species with significant regression coefficients at $\alpha = 0.05$) to calculate the probability that the divers could have seen red grouper in their dive/habitats (Table A-2, Figure A-2).

The critical value for the threshold was the threshold with the smallest absolute difference between the observed number of dive/habitats and the predicted number. For the visual survey, the threshold was 0.308 and with that threshold, the regression predicted 563 dive/habitats to have observed red grouper. However, two of those dive/habitats were lacking necessary pieces of information such that there were 561 dive/habitats with complete information.

Once the 561 dive/habitats were selected, we estimated the number of red grouper per dive per habitat by year with a generalized linear model (GLM). Because there were many zero counts of red grouper (319 counts) and the GLM with a Poisson distribution and a log link indicated that the data were over-dispersed (mean deviance = 1.79), we used two GLMs (Lo *et al*. 1992). The first GLM used a binomial distribution with a logit link to estimate the proportion of dive/habitats that observed red grouper per year and the second GLM model used a gamma distribution with a log link to estimate the number of red grouper per point count on those dives that saw red grouper. Potential explanatory variables for both GLMs were year, month (May-October), zone (A-D), bottom habitat relief, bottom habitat type, percent of biological cover, depth category, secchi distance, and the number of counts for that dive/habitat. Depth was categorized by 4-meter intervals (13.1 ft) with all depths greater than 16 m (52.5 ft) combined. Secchi was categorized by two-meter intervals from six or less meters to 26 or more meters (19.7 - 85.3 ft). Percent of biological cover of the bottom was categorized in 10% intervals with percentages less than 30% being grouped into 30% and percentages greater than 90% were grouped into 90%.

Variables that were included in the GLMs were chosen in a stepwise manner using the smallest Akaike Information Criterion (AIC) at each level of the number of predictor variables, provided that the variable was significant at the $\alpha = 0.05$ level in the regression based on two times the change in log-likelihood (Table A-3). Variability in the catch rates was estimated with a Monte Carlo approach that used the least squares means by year and their standard errors from the GLM. 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. The process was repeated each year based on the number of positive dive/habitats.

The model to the binomial portion of the model, the proportion positive, reduced the mean deviance (deviance/degrees of freedom) by 5.3% with bottom habitat relief accounting for 2.6%, year (1.5%), and zone (1.1%). The fit was reasonable (Figure A-4). The fit to the model for the number of red groupers observed on positive dives (242 dive/habitats) was better than that for the proportion positive and reduced the mean deviance by 24.8% with year accounting for 10.1% and the other significant variables were zone (3.9%), secchi distance (5.8%, visibility), number of point counts within the dive/habitat (2.7%), and depth categories (2.3%).

According to the dive/habitats selected by S&M, the numbers of red grouper seen increased from 1999 to 2001 and then declined to 2004 and been stable since then (Figure A-5). More red grouper were observed in Zone B (Figure A-6).

We also looked at selecting the dive/habitats using cluster analysis as an alternative to the Stephens and MacCall logistic regression. Cluster analysis has frequently been used to identify groups in fish assemblages (Mueter and Norcross 2000, Rooper 2008, and Shertzer and Williams 2008) We used the same visual survey dive/habitats that were used with the S&M except that the number of fish observed on a dive/habitat were not converted to presence or absence but rather left as the number of red grouper per dive/habitat. The similarity between pairs of species by dive/habitat were calculated with the Morisita Similarity Index because we used the number of red grouper observed and the similarity information was input to the hierarchical cluster routine that used average cluster linkage. The details are in Muller and Acosta (2009).

The other species in the cluster that contained red grouper was hogfish, *Lachnolaimus maximus*, gray angel fish, *Pomacanthus arcuatus*, and French angelfish, *P. paru* (Figure A-7). There were 2,006 dive/habitats that contained at least one of the four species.

The mean number of red grouper observed per dive/habitat was estimated with a GLM using a Poisson distribution with a log link using the 2,006 dive/habitats. The potential variables were same as those in the S&M proportion positive model except that the dependent variable was now the number of red grouper seen on the dive/habitat and the number of point counts in that observation was another potential explanatory variable. The fit of the model was quite reasonable (Figure A-8) and reduced the mean deviance by 17.4% with number of point counts in a bottom habitat relief per dive accounting for 5.0%, depth category (4.3%), year (3.8%), zone (1.6%), secchi distance (1.0%), percent biological cover (1.8%), bottom habitat relief (0.6%), and month (0.2%) (Table A-4).

The catch rates for red grouper from the visual survey increased from 1999 to 2000 and then decreased to 2004; the rates for 2006 and 2007 were similar to the 2004 value (Figure A-9). The catch rates calculated with dive/habitats selected with cluster analysis were similar to the nominal catch rates (correlation $r = 0.93$, $df = 6$, $P < 0.05$) and to the catch rates from the S&M dive/habitats (correlation $r = 0.91$, $df = 6$, $P < 0.05$).

Choosing the index to represent the pattern in red grouper observed by the visual survey is difficult because all three methods produced similar results (Figure A-10). We eliminated the nominal index because it only includes positive dives and there were probably other dives that could have seen red groupers, we choose the index developed from cluster analysis because it included more dive/ habitats, 2006 vs. 242 dive/habitats and it had smaller coefficients of variations than did the index developed from dive/habitats selected by S&M.

To determine the appropriate ages for this index, we used the 95% observed length range, as estimated by the visual survey, and then calculated the corresponding ages. We did not have a von Bertalanffy growth equation for red grouper from the South Atlantic and so we used the equation from Lombardi-Carlson *et al.* (2006) from the northeastern Gulf of Mexico. The 95% length range was from 200 mm TL to 700 mm TL (Figure A-11) and, after rearranging the von Bertalanffy growth equation from Lombardi-Carlson t al. (L_∞ = 854, K = 0.16, to = -0.19, 2006), these lengths corresponded to ages 1 through 10. If the Life History group brings a growth equation for red grouper to the data workshop that was developed using otoliths from the South Atlantic, then these ages should be modified.

Therefore at this time, we recommend using the index from cluster analysis and applying that index to ages 1 through 10.

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Table A-1. The number of dive/habitats, nominal visual count, the visual count from dive/habitats selected by the Stephens and MacCall regreesion, and from the dive/habitats selected by cluster analysis, together with their coefficients of variation, their index values scaled to their means. The number of dive/habitats is the number that observed red grouper.

	Nominal				Stephens and MacCall				Cluster analysis			
Year	Number of dive/habitats	Mean number per dive/habitat	Coefficient of variation	Index Scaled to mean	Number of dive/habitats	Mean number per dive/habitat	Coefficient of variation	Index Scaled to mean	Number of dive/habitats	Mean number per dive/habitat	Coefficient of variation	Index Scaled to mean
1999	31	1.548	0.101	0.95	20	0.430	0.220	0.71	154	0.101	0.195	0.87
2000	54	1.741	0.071	1.07	32	0.697	0.224	1.15	173	0.185	0.172	1.58
2001	97	1.990	0.126	1.23	48	0.985	0.169	1.62	268	0.178	0.170	1.53
2002	84	1.679	0.084	1.03	32	0.782	0.193	1.29	263	0.153	0.176	1.31
2003	74	1.568	0.110	0.97	30	0.529	0.212	0.87	274	0.114	0.196	0.98
2004	57	1.368	0.067	0.84	25	0.351	0.292	0.58	273	0.072	0.188	0.62
2005												
2006	58	1.328	0.083	0.82	32	0.383	0.187	0.63	301	0.072	0.191	0.62
2007	56	1.464	0.093	0.90	23	0.298	0.250	0.49	300	0.086	0.186	0.74
Total	511				242				2006			

Table A-2. Logistic regression coefficients and their standard errors for species associated with red grouper.

			Regression	
NODC code	Scientific name	Common name	Coefficient	Std Error
		Intercept	-2.8754	0.1687
8835020402	*Epinephelus adscensionis*	Rock hind	-0.8389	0.3269
8835020406	*Epinephelus guttatus*	Red hind	0.7712	0.2586
8835400100	*Haemulon spp.*	Grunts spp.	0.4775	0.165
8835400102	*Haemulon plumieri*	White grunt	0.7532	0.1501
8835400108	*Haemulon flavolineatum*	French grunt	-0.3215	0.1213
8835400306	*Anisotremus virginicus*	Porkfish	0.3379	0.1147
8835550303	*Holacanthus tricolor*	Rock beauty	-0.4711	0.1425
8835550401	*Pomacanthus arcuatus*	Gray angelfish	0.5223	0.1117
8839010302	*Bodianus rufus*	Spanish hogfish	-0.3144	0.1489
8839010901	*Lachnolaimus maximus*	Hogfish	0.7929	0.1235
8860020201	*Balistes capriscus*	Gray triggerfish	1.2744	0.1939
8860020202	*Balistes vetula*	Queen triggerfish	1.2151	0.2307

Table A-3a. Step-wise identification of variables to include in the generalized linear model (binomial distribution and a logit link) for the proportion of positive dive/habitats based on the lowest Akaike Information Criterion (AIC) using intercepts selected by the Stephens and MacCall regression. 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 AIC.

Variables	df	Deviance	mean dev	Δ mean de	% mean d	Cum %	log like	Δ log like	-2*log like	df X^2	Prob Ho	AIC
Null	560	767.1091	1.3698				-383.555			1		769.11
Year	553	744.2809	1.3459	0.0239	1.74%		-372.141	-11.4140	22.828	7	0.001826	760.28
Month	555	763.1757	1.3751	-0.0053	-0.39%		-381.588	-1.9667	3.933	5	0.559044	775.18
Zone	557	754.3030	1.3542	0.0156	1.14%		-377.152	-6.4030	12.806	3	0.005075	762.30
BottomHab	558	744.1929	1.3337	0.0361	2.64%	2.6%	-372.097	-11.4580	22.916	2	1.06E-05	750.19
BottomHab	558	760.4917	1.3629	0.0069	0.50%		-380.246	-3.3087	6.617	2	0.036564	766.49
Biocover	554	759.6656	1.3712	-0.0014	-0.10%		-379.833	-3.7217	7.443	6	0.281779	773.67
Dep_cat	556	761.0111	1.3687	0.0011	0.08%		-380.506	-3.0490	6.098	4	0.191948	771.01
Secchi	550	759.6702	1.3812	-0.0114	-0.83%		-379.835	-3.7194	7.439	10	0.683471	781.67
Num coun	557	753.4210	1.3526	0.0172	1.26%		-376.711	-6.8440	13.688	3	0.003362	761.42
With BottomHabitatRelief												
Year	551	723.1654	1.3125	0.0212	1.55%	4.2%	-361.583	-10.5138	21.028	7	0.00373	743.17
Month	553	739.9775	1.3381	-0.0044	-0.32%		-369.989	-2.1078	4.216	5	0.518811	755.98
Zone	555	734.1782	1.3228	0.0109	0.80%		-367.089	-5.0074	10.015	3	0.018441	746.18
BottomHab	556	742.1065	1.3347	-0.0010	-0.07%		-371.053	-1.0432	2.086	2	0.352325	752.11
Biocover	552	736.8015	1.3348	-0.0011	-0.08%		-368.401	-3.6957	7.391	6	0.286162	754.80
Dep_cat	554	740.7287	1.3371	-0.0034	-0.25%		-370.364	-1.7321	3.464	4	0.483343	754.73
Secchi	548	740.7729	1.3518	-0.0181	-1.32%		-370.387	-1.7100	3.420	10	0.969745	766.77
Num coun	555	740.5187	1.3343	-0.0006	-0.04%		-370.259	-1.8372	3.674	3	0.298837	752.52
With BottomHabitatRelief and year												
Month	546	719.0593	1.3170	-0.0045	-0.33%		-359.530	-2.0531	4.106	5	0.534229	749.06
Zone	548	710.6574	1.2968	0.0157	1.15%	5.3%	-355.329	-6.2540	12.508	3	0.005831	736.66
BottomHab	549	718.9893	1.3096	0.0029	0.21%		-359.495	-2.0880	4.176	2	0.123935	742.99
Biocover	545	715.9921	1.3137	-0.0012	-0.09%		-357.996	-3.5866	7.173	6	0.305126	747.99
Dep_cat	547	719.1173	1.3147	-0.0022	-0.16%		-359.559	-2.0241	4.048	4	0.399522	747.12
Secchi	541	719.7953	1.3305	-0.0180	-1.31%		-359.898	-1.6850	3.370	10	0.971329	759.80
Num coun	548	720.8637	1.3154	-0.0029	-0.21%		-360.432	-1.1508	2.302	3	0.512214	746.86
With BottomHabitatRelief, year, and zone												
Month	543	706.7720	1.3016	-0.0048	-0.35%		-353.386	-1.9427	3.885	5	0.566031	742.77
BottomHab	546	706.5526	1.2941	0.0027	0.20%		-353.276	-2.0524	4.105	2	0.128426	736.55
Biocover	542	703.7236	1.2984	-0.0016	-0.12%		-351.862	-3.4669	6.934	6	0.327013	741.72
Dep_cat	544	704.7261	1.2955	0.0013	0.09%		-352.363	-2.9657	5.931	4	0.20433	738.73
Secchi	538	708.2963	1.3165	-0.0197	-1.44%		-354.148	-1.1805	2.361	10	0.99275	754.30
Num coun	545	708.7687	1.3005	-0.0037	-0.27%		-354.384	-0.9444	1.889	3	0.595804	740.77

Table A-3b. Step-wise identification of variables to include in the generalized linear model (log-normal distribution and identity link) for the number of red grouper per point-count seen on positive dive/habitats based on the lowest Akaike Information Criterion (AIC) using intercepts selected by the Stephens and MacCall regression. 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 AIC.

Variables	df	Deviance	mean dev	Δ mean de	% mean de	Cum %	log like	Δ log like	-2*log like	df X^2	Prob Ho	AIC
Null	241	100.9746	0.4190				-345.893			2		695.79
Year	234	88.0995	0.3765	0.0425	10.14%	10.1%	-328.390	-17.5033	35.007	7	1.12E-05	674.78
Month	236	93.9761	0.3982	0.0208	4.96%		-336.660	-9.2329	18.466	5	0.002416	687.32
Zone	238	96.7129	0.4064	0.0126	3.01%		-340.346	-5.5472	11.094	3	0.011226	690.69
BottomHabitatRelief	239	98.2374	0.4110	0.0080	1.91%		-342.356	-3.5368	7.074	2	0.029106	692.71
BottomHabitatType	239	100.9395	0.4223	-0.0033	-0.79%		-345.848	-0.0448	0.090	2	0.956189	699.70
Biocover	235	92.6426	0.3942	0.0248	5.92%		-334.827	-11.0656	22.131	6	0.001146	685.65
Dep_cat	237	97.3854	0.4109	0.0081	1.93%		-341.236	-4.6567	9.313	4	0.053726	694.47
Secchi	231	89.7853	0.3887	0.0303	7.23%		-330.814	-15.0785	30.157	10	0.000807	685.63
Num counts	238	93.6374	0.3934	0.0256	6.11%		-336.197	-9.6961	19.392	3	0.000227	682.39
With year												
Month	229	83.9499	0.3666	0.0099	2.36%		-322.228	-6.1619	12.324	5	0.03061	672.46
Zone	231	83.2075	0.3602	0.0163	3.89%	14.0%	-321.095	-7.2949	14.590	3	0.002203	666.19
BottomHabitatRelief	232	86.8120	0.3742	0.0023	0.55%		-326.508	-1.8819	3.764	2	0.1523	675.02
BottomHabitatType	232	88.0809	0.3797	-0.0032	-0.76%		-328.363	-0.0271	0.054	2	0.973264	678.73
Biocover	228	82.8683	0.3635	0.0130	3.10%		-320.574	-7.8158	15.632	6	0.015874	671.15
Dep_cat	230	84.0973	0.3656	0.0109	2.60%		-322.452	-5.9381	11.876	4	0.018296	670.90
Secchi	224	79.3432	0.3542	0.0223	5.32%		-315.038	-13.3519	26.704	10	0.0029	668.08
Num counts	231	84.0625	0.3639	0.0126	3.01%		-322.399	-5.9910	11.982	3	0.007445	668.80
With year and zone												
Month	226	80.7961	0.3575	0.0027	0.64%		-317.347	-3.7474	7.495	5	0.186364	668.69
BottomHabitatRelief	229	82.7724	0.3615	-0.0013	-0.31%		-320.426	-0.6684	1.337	2	0.512528	668.85
BottomHabitatType	229	82.9007	0.3620	-0.0018	-0.43%		-320.624	-0.4710	0.942	2	0.624378	669.25
Biocover	225	78.7525	0.3500	0.0102	2.43%		-314.087	-7.0076	14.015	6	0.029467	664.17
Dep_cat	227	80.9875	0.3568	0.0034	0.81%		-317.649	-3.4460	6.892	4	0.141707	667.30
Secchi	221	74.2400	0.3359	0.0243	5.80%	19.8%	-306.592	-14.5026	29.005	10	0.001244	657.18
Num counts	228	80.2483	0.3520	0.0082	1.96%		-316.481	-4.6135	9.227	3	0.02642	662.96
With year, zone, and secchi												
Month	216	71.3890	0.3305	0.0054	1.29%		-301.629	-4.9632	9.926	5	0.077348	657.26
BottomHabitatRelief	219	73.7395	0.3367	-0.0008	-0.19%		-305.734	-0.8580	1.716	2	0.424009	659.47
BottomHabitatType	219	73.6579	0.3363	-0.0004	-0.10%		-305.594	-0.9983	1.997	2	0.368505	659.19
Biocover	215	70.4082	0.3275	0.0084	2.00%		-299.877	-6.7147	13.429	6	0.036702	655.75
Dep_cat	217	70.8438	0.3265	0.0094	2.24%		-300.658	-5.9340	11.868	4	0.01836	653.32
Num counts	218	70.7578	0.3246	0.0113	2.70%	22.5%	-300.504	-6.0878	12.176	3	0.006805	651.01
With year, zone, secchi, and num_counts												
Month	213	68.3774	0.3210	0.0036	0.86%		-296.175	-4.3289	8.658	5	0.123517	652.35
BottomHabitatRelief	216	70.6805	0.3272	-0.0026	-0.62%		-300.366	-0.1384	0.277	2	0.87075	654.73
BottomHabitatType	216	70.1007	0.3245	0.0001	0.02%		-299.323	-1.1809	2.362	2	0.307002	652.65
Biocover	212	67.6029	0.3189	0.0057	1.36%		-294.736	-5.7687	11.537	6	0.073121	651.47
Dep_cat	214	67.4420	0.3151	0.0095	2.27%	24.8%	-294.435	-6.0697	12.139	4	0.016344	646.87
With year, zone, secchi, num_counts, and dep_cat												
Month	209	65.8826	0.3152	-0.0001	-0.02%		-291.480	-2.9545	5.909	5	0.315175	650.96
BottomHabitatRelief	212	67.3385	0.3176	-0.0025	-0.60%		-294.240	-0.1942	0.388	2	0.823493	650.48
BottomHabitatType	212	66.8084	0.3151	0.0000	0.00%		-293.242	-1.1925	2.385	2	0.303462	648.48
Biocover	208	65.5422	0.3151	0.0000	0.00%		-290.826	-3.6083	7.217	6	0.30128	651.65

Table A-4. Step-wise identification of variables to include in the generalized linear model (Poisson distribution with a log link) for the number of red grouper seen on dive/habitats based on the lowest Akaike Information Criterion (AIC) using intercepts selected by cluster analysis. The GLM used a Poisson distribution with a log link. 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 AIC.

Variables	df	Deviance	mean dev	Δ mean de	% mean d	Cum %	log like	Δ log like	-2*log like	df X^2	Prob Ho	AIC
Null	2005	2625.7975	1.3096				-1893.911			1		3789.82
Year	1998	2509.8702	1.2562	0.0534	4.1%		-1835.947	-57.9637	115.927	7	5.39E-22	3687.89
Month	2000	2606.7349	1.3034	0.0062	0.5%		-1884.379	-9.5313	19.063	5	0.001871	3780.76
Zone	2002	2578.7296	1.2881	0.0215	1.6%		-1870.377	-23.5340	47.068	3	3.36E-10	3748.75
BottomHabitatRelief	2003	2506.3275	1.2513	0.0583	4.5%		-1834.176	-59.7350	119.470	2	1.14E-26	3674.35
BottomHabitatType	2003	2605.7912	1.3009	0.0087	0.7%		-1883.907	-10.0032	20.006	2	4.53E-05	3773.81
Biocover	1998	2602.0309	1.3023	0.0073	0.6%		-1882.027	-11.8833	23.767	7	0.001252	3780.05
Dep_cat	1999	2510.5228	1.2559	0.0537	4.1%		-1836.273	-57.6374	115.275	6	1.6E-22	3686.55
Secchi	1994	2596.8502	1.3023	0.0073	0.6%		-1879.437	-14.4737	28.947	11	0.002313	3782.87
Num counts	2002	2490.3958	1.2440	0.0656	5.0%	5.0%	-1826.210	-67.7009	135.402	3	3.71E-29	3660.42
With num_counts												
Year	1995	2386.6362	1.1963	0.0477	3.6%		-1774.330	-51.8798	103.760	7	1.8E-19	3570.66
Month	1997	2474.4626	1.2391	0.0049	0.4%		-1818.243	-7.9666	15.933	5	0.007037	3654.49
Zone	1999	2460.5004	1.2309	0.0131	1.0%		-1811.262	-14.9477	29.895	3	1.45E-06	3636.52
BottomHabitatRelief	2000	2423.4097	1.2117	0.0323	2.5%		-1792.717	-33.4930	66.986	2	2.85E-15	3597.43
BottomHabitatType	2000	2479.2841	1.2396	0.0044	0.3%		-1820.654	-5.5558	11.112	2	0.003865	3653.31
Biocover	1995	2465.2954	1.2357	0.0083	0.6%		-1813.660	-12.5502	25.100	7	0.000728	3649.32
Dep_cat	1996	2371.6643	1.1882	0.0558	4.3%	9.3%	-1766.844	-59.3657	118.731	6	3.01E-23	3553.69
Secchi	1991	2455.2870	1.2332	0.0108	0.8%		-1808.655	-17.5544	35.109	11	0.000238	3647.31
With num_counts and dep_cat												
Year	1989	2263.3171	1.1379	0.0503	3.8%	13.1%	-1712.670	-54.1736	108.347	7	2.02E-20	3459.34
Month	1991	2358.7708	1.1847	0.0035	0.3%		-1760.397	-6.4468	12.894	5	0.024397	3550.79
Zone	1993	2331.2690	1.1697	0.0185	1.4%		-1746.646	-20.1977	40.395	3	8.78E-09	3519.29
BottomHabitatRelief	1994	2344.7888	1.1759	0.0123	0.9%		-1753.406	-13.4378	26.876	2	1.46E-06	3530.81
BottomHabitatType	1994	2364.8105	1.1860	0.0022	0.2%		-1763.417	-3.4269	6.854	2	0.032487	3550.83
Biocover	1989	2349.1133	1.1811	0.0071	0.5%		-1755.569	-11.2755	22.551	7	0.00204	3545.14
Secchi	1985	2336.7678	1.1772	0.0110	0.8%		-1749.396	-17.4483	34.897	11	0.000258	3540.79
With num_counts, dep_cat, and year												
Month	1984	2251.2127	1.1347	0.0032	0.2%		-1706.618	-6.0522	12.104	5	0.033385	3457.24
Zone	1986	2217.1239	1.1164	0.0215	1.6%	14.8%	-1689.574	-23.0966	46.193	3	5.16E-10	3419.15
BottomHabitatRelief	1987	2246.1132	1.1304	0.0075	0.6%		-1704.069	-8.6019	17.204	2	0.000184	3446.14
BottomHabitatType	1987	2252.0030	1.1334	0.0045	0.3%		-1707.013	-5.6571	11.314	2	0.003493	3452.03
Biocover	1982	2241.2228	1.1308	0.0071	0.5%		-1701.623	-11.0472	22.094	7	0.002447	3451.25
Secchi	1978	2235.9136	1.1304	0.0075	0.6%		-1698.969	-13.7018	27.404	11	0.003992	3453.94
With num_counts, dep_cat, year, and zone												
Month	1981	2206.8124	1.1140	0.0024	0.2%		-1684.418	-5.1558	10.312	5	0.066873	3418.84
BottomHabitatRelief	1984	2203.5321	1.1107	0.0057	0.4%		-1682.778	-6.7959	13.592	2	0.001118	3409.56
BottomHabitatType	1984	2205.1078	1.1114	0.0050	0.4%		-1683.566	-6.0081	12.016	2	0.002459	3411.13
Biocover	1979	2191.1538	1.1072	0.0092	0.7%		-1676.589	-12.9851	25.970	7	0.00051	3407.18
Secchi	1975	2179.1794	1.1034	0.0130	1.0%	15.7%	-1670.602	-18.9723	37.945	11	7.99E-05	3403.20
With num_counts, dep_cat, year, zone, and secchi												
Month	1970	2169.8992	1.1015	0.0019	0.1%		-1665.961	-4.6401	9.280	5	0.098396	3403.92
BottomHabitatRelief	1973	2164.3093	1.0970	0.0064	0.5%		-1663.167	-7.4350	14.870	2	0.00059	3392.33
BottomHabitatType	1973	2168.6432	1.0992	0.0042	0.3%		-1665.333	-5.2681	10.536	2	0.005153	3396.67
Biocover	1968	2150.9186	1.0929	0.0105	0.8%	16.5%	-1656.471	-14.1304	28.261	7	0.000197	3388.94
With num_counts, dep_cat, year, zone, secchi, and biocover												
Month	1963	2141.4575	1.0909	0.0020	0.2%		-1651.741	-4.7305	9.461	5	0.09203	3389.48
BottomHabitatRelief	1966	2132.6546	1.0848	0.0081	0.6%	17.2%	-1647.339	-9.1319	18.264	2	0.000108	3374.68
BottomHabitatType	1966	2138.4131	1.0877	0.0052	0.4%		-1650.218	-6.2527	12.505	2	0.001925	3380.44
With num_counts, dep_cat, year, zone, secchi, biocover, and BottomHabitatRelief												
Month	1961	2121.2477	1.0817	0.0031	0.2%	17.4%	-1641.636	-5.7035	11.407	5	0.043882	3373.27
BottomHabitatType	1964	2127.6921	1.0833	0.0015	0.1%		-1644.858	-2.4813	4.963	2	0.083634	3373.72
With num_counts, dep_cat, year, zone, secchi, biocover, BottomHabitatRelief, month												
BottomHabitatType	1959	2115.6406	1.0800	0.0017	0.1%		-1638.832	-2.8036	5.607	2	0.060592	3375.66

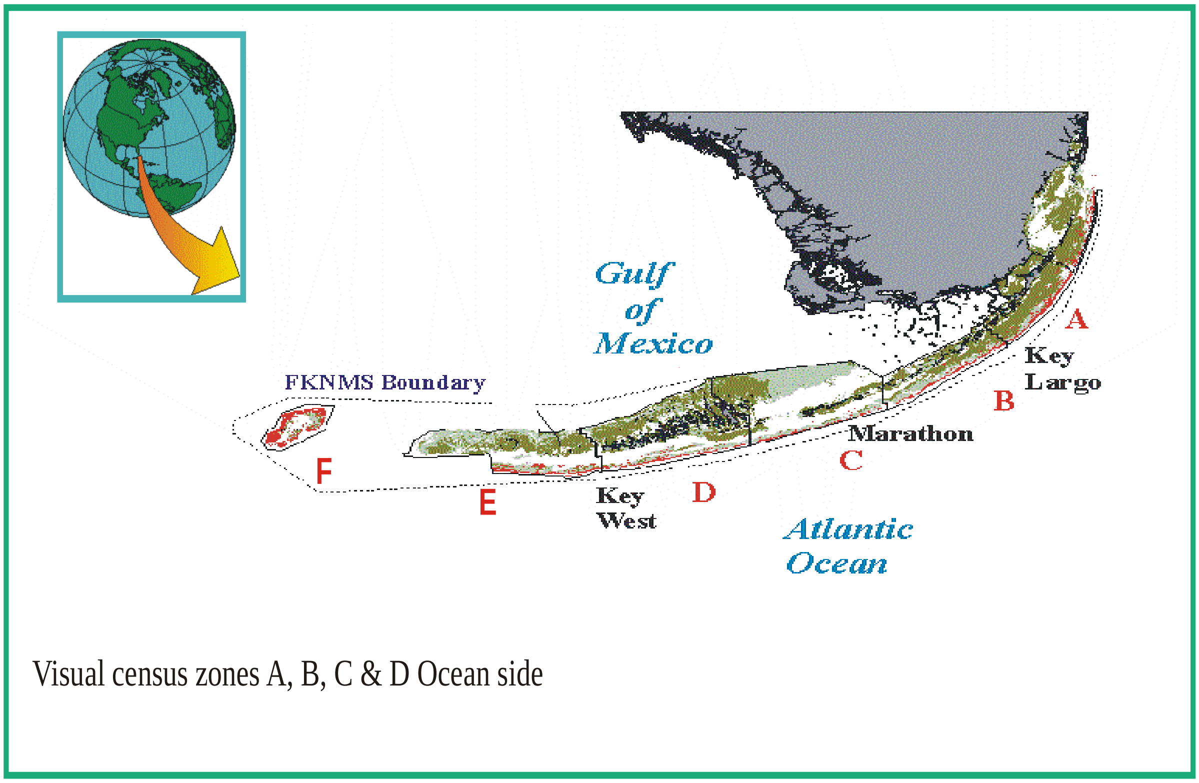


Figure A-1. Map of the Florida Keys' Fisheries-Independent Monitoring Program sampling areas, in the Florida Keys National Marine Sanctuary (FKNMS).

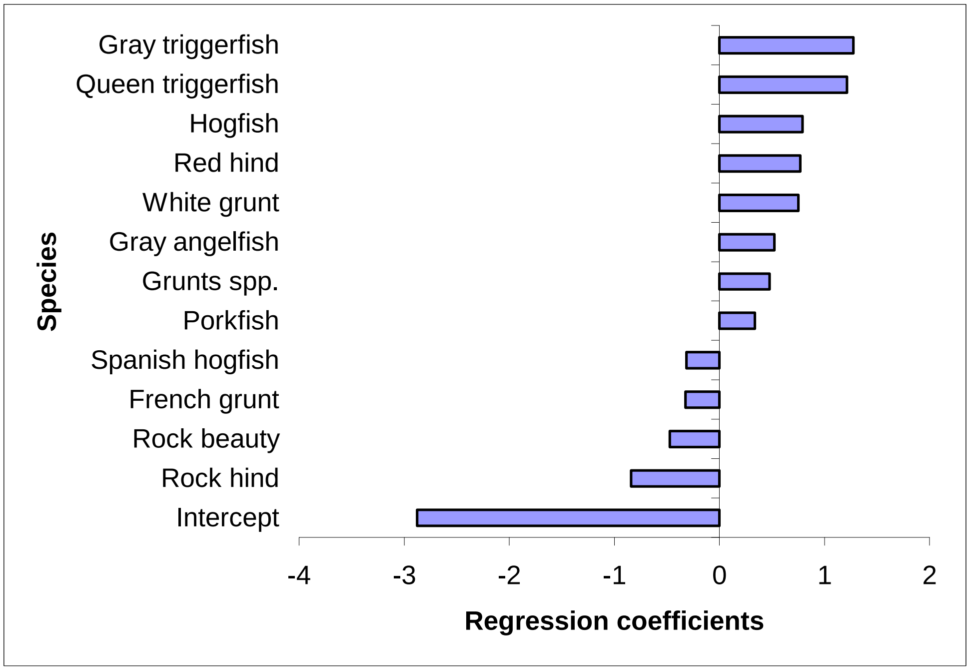


Figure A-2 Species with significant regression coefficients for calculating the threshold for whether a dive/habitat should be selected for inclusion in calculating the catch rates.

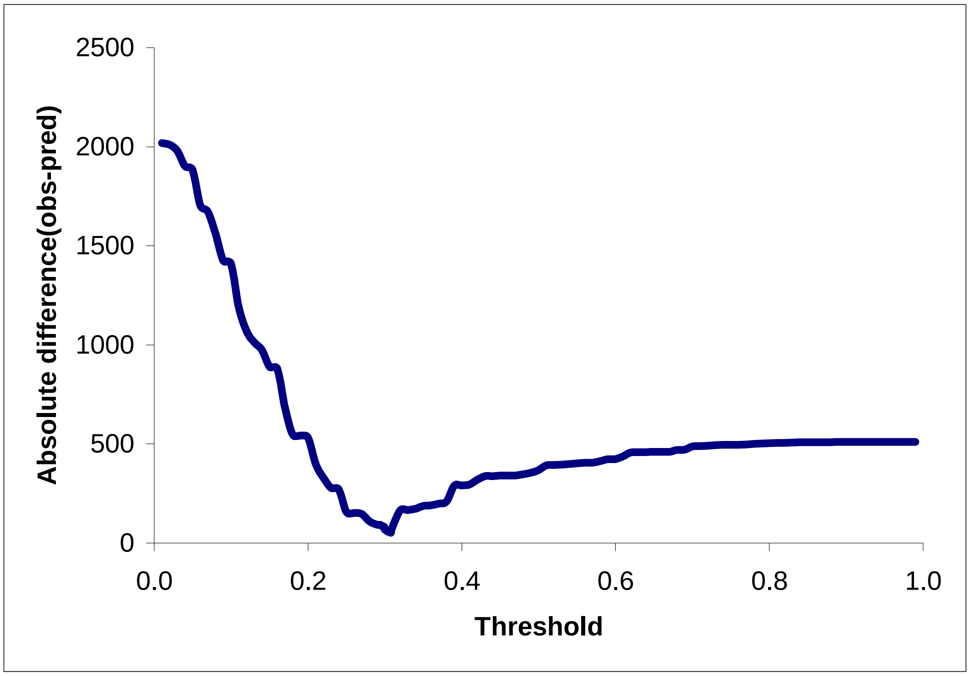


Figure A-3. The absolute differences between observed and predicted dives per habitat for red grouper by threshold value from Stephens and MacCall's logistic regression.

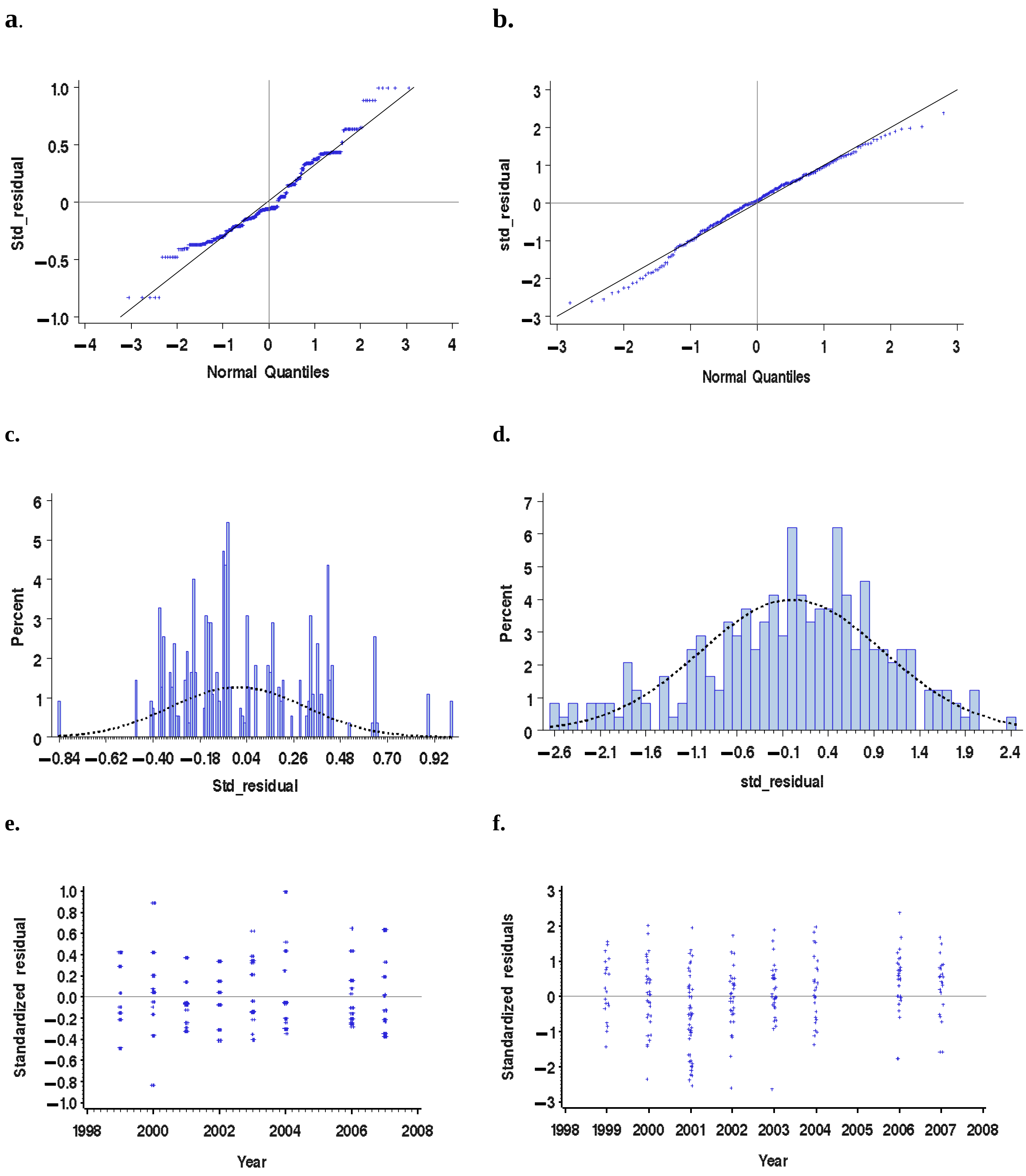


Figure A-4. Quantile plot (a) and distribution (c) and annual standardized residuals (e) of the generalized linear model (GLM) using a binomial distribution with a logit link to estimate the annual proportion of positive dive/habitats and a quantile plot (b) and distribution (d) and annual standardized residuals (f) of the GLM using a log-normal distribution with an identity link for the number of black grouper observed per point-count on positive dive/habitats from dive/habitat point-counts selected with the Stephens and MacCall regression..

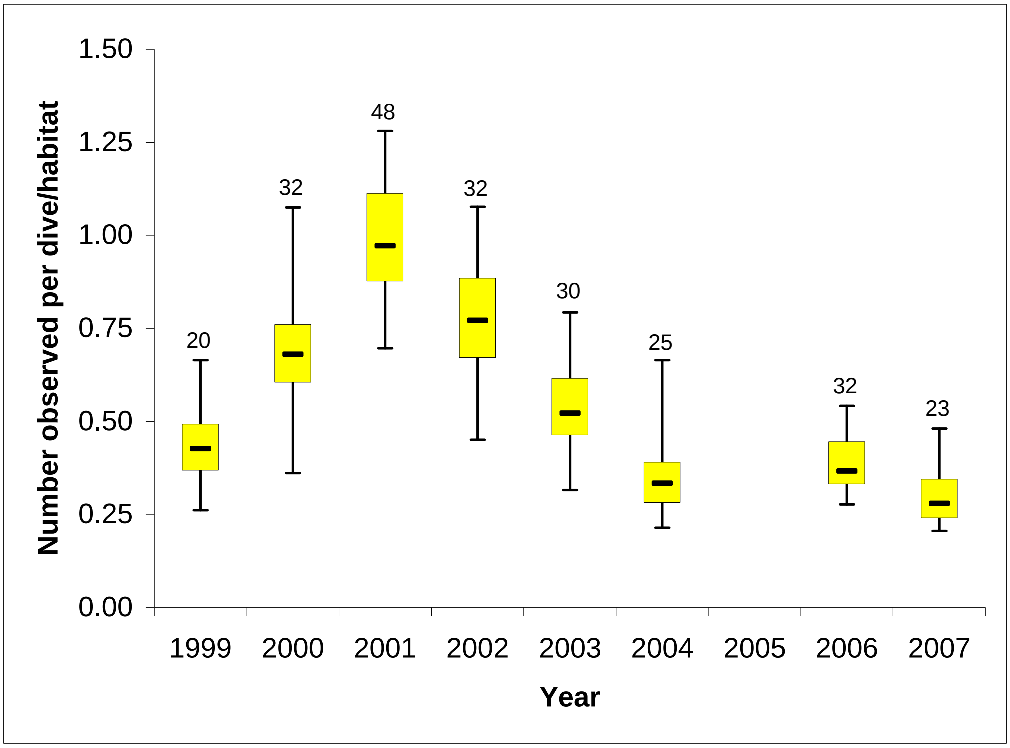


Figure A-5. The estimated annual number of red grouper per dive/habitat point-count observed by the visual survey. Vertical line – 95% confidence interval, box – inter-quartile range, horizontal line – median, and the number is the number of dive/habitats where red grouper were observed.

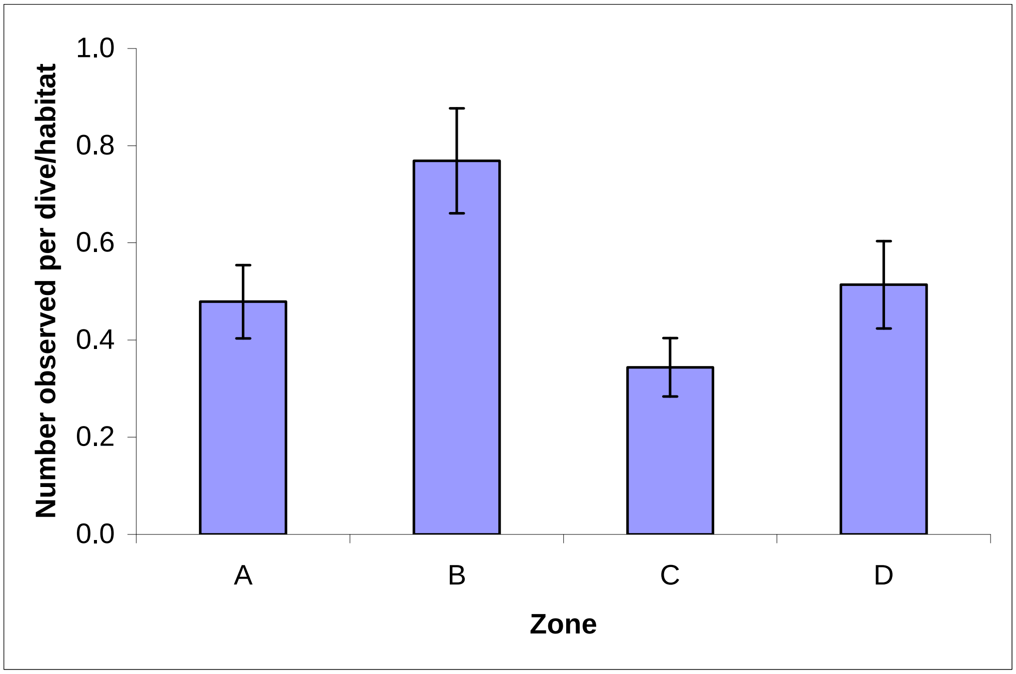


Figure A-6. Number of red grouper per dive/habitat point-count by zone observed by the visual survey. Vertical line – 95% confidence interval, box – inter-quartile range, horizontal line – median, and the number is the number of dive/habitats where red grouper were observed.

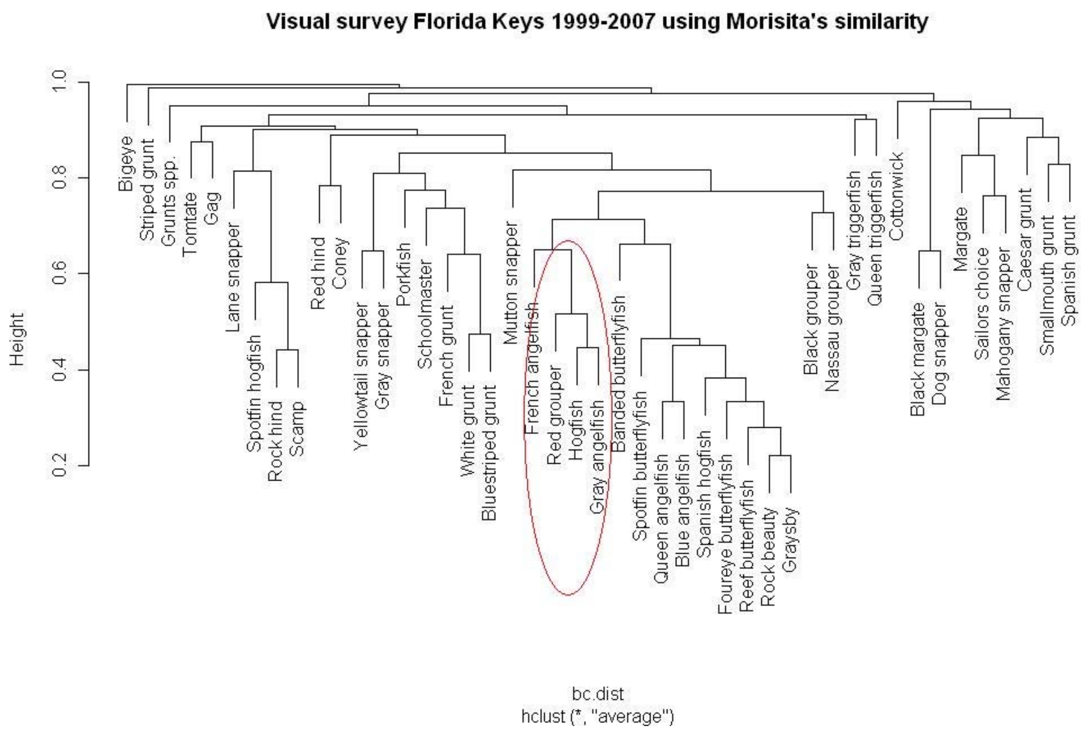
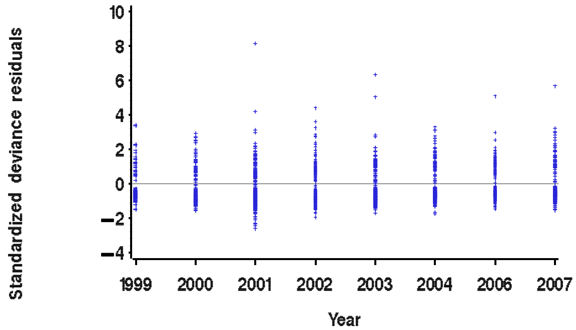
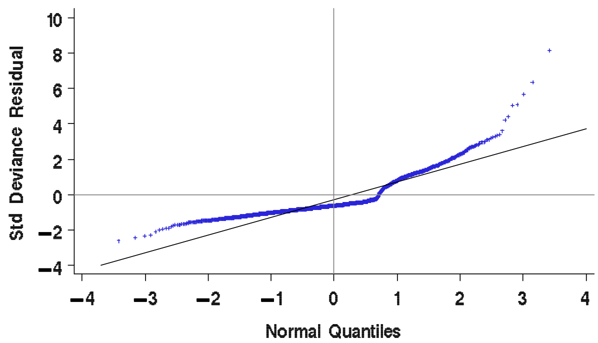


Figure A-7. Species clusters identified with hierarchical cluster analysis of pair-wise similarity of species for visual survey data. The cluster containing red grouper is indicated by the ellipse.

a.



b.



c.

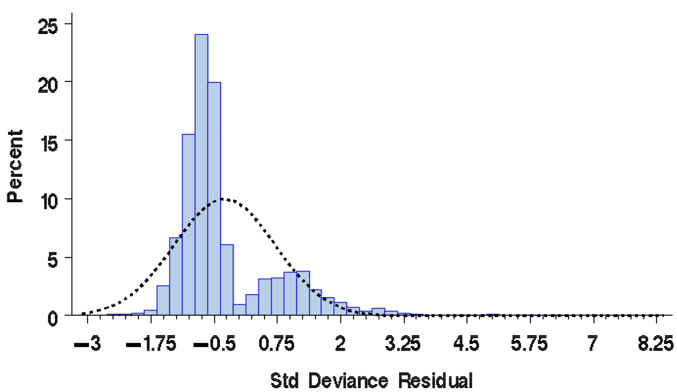


Figure A-8. Standardized residuals by year (a), quantile plot (b) and the distribution of the standardized residuals (c) from the GLM using a Poisson distribution with a log link for the number of red grouper observed per dive/habitat selected with cluster analysis.

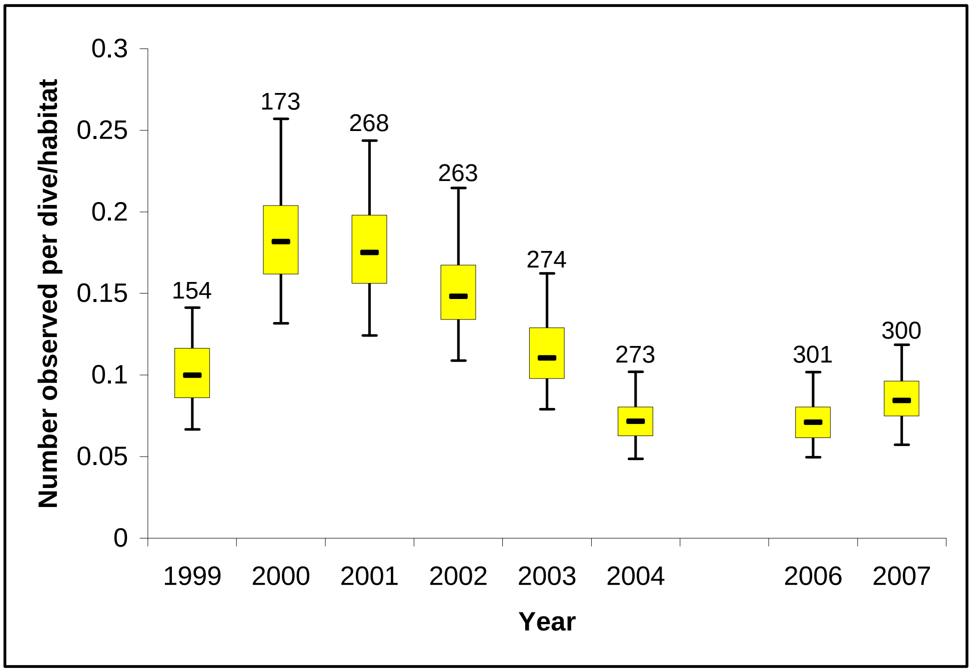


Figure A-9. The estimated annual number of red grouper per dive per bottom habitat observed by the visual survey estimated from dive/habitat point-counts selected by cluster analysis. Vertical line – 95% confidence interval, box – inter-quartile range, horizontal line – median, and the number is the number of dive/habitats where red grouper were observed.

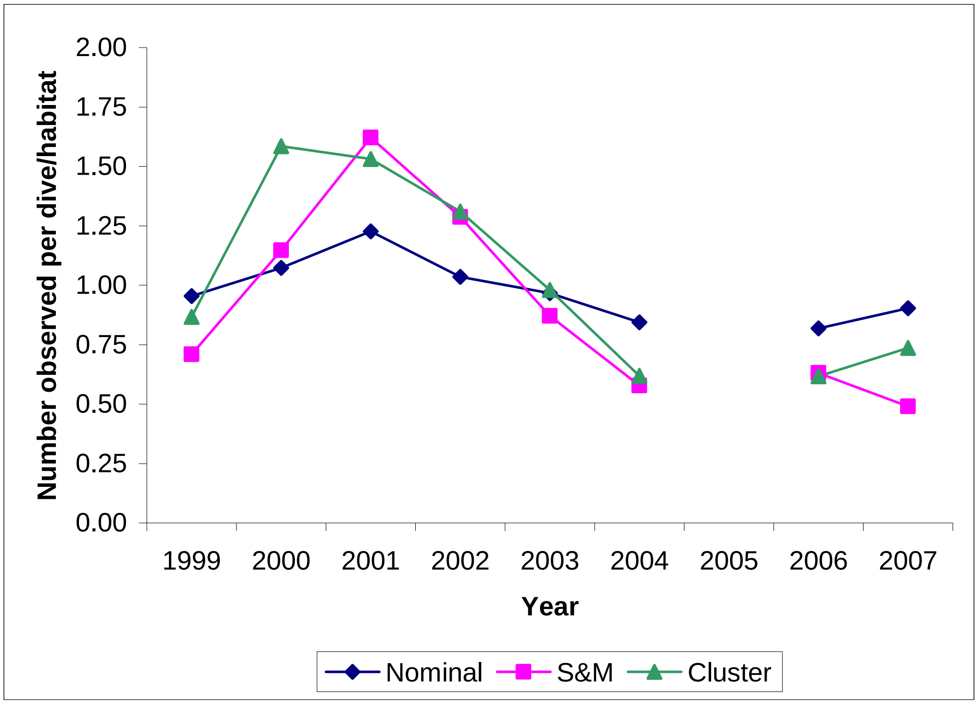


Figure A-10. Comparison of annual catch rates calculated from the positive red grouper dive/habitats (Nominal), from dive/habitats selected with the Stephens and MacCall logistic regression (S&M), and from dive habitats selected by cluster analysis (Cluster).

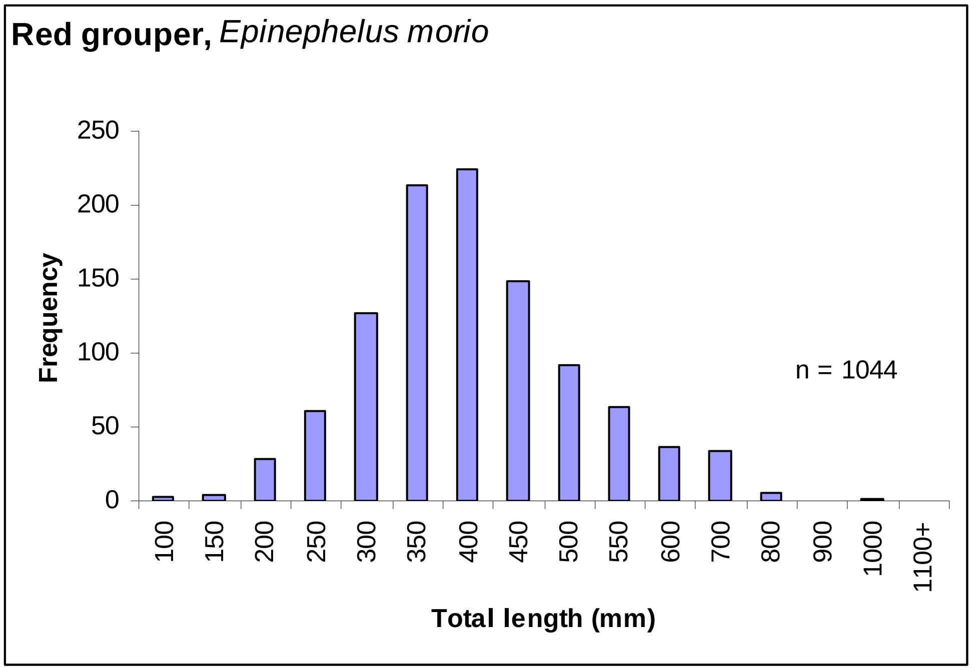


Figure A-11. Total length distribution of red grouper as estimated by divers aggregated over dives from 1999-2007 .