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

Robert Muller and Alejandro Acosta
Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute
St. Petersburg, FL 33701-5520
12 June 2009

The description of the Florida Fish and Wildlife Conservation Commission (FWC) visual census was taken from Acosta and Muller (2008) and updated as necessary for the current analyses.

Survey geographic range

The survey is conducted in the open-waters of the Florida Keys National Marine Sanctuary (FKNMS). For the purposes of the Fisheries Research, Fisheries Independent program, the sampling universe in the FKNMS was divided into six geographical zones, designated A through F, four of which were sampled during the present study; (Figure 1). Zone A includes all of the waters surrounding Key Largo, the northernmost and largest island in the chain, Zone B extends from the southwestern end of Key Largo along the rest of the Upper Keys to Long Key, Zone C encompasses the Middle Keys from Long Key to Big Pine Key, while Zone D surrounds the Lower Keys (Big Pine Key to Key West) (Figure 1). Visual sampling was only conducted on the Atlantic side of the Keys.

Survey sampling method and gear:

Visual Census

The Finfish program currently uses the stationary point count method for its visual surveys. In this method, a stationary diver records the number of individuals of each target species that are observed within an imaginary five-meter radius cylinder and assigns fish to length intervals. Two divers conduct a total of four point counts at each site. During the visual survey, each diver lays out a 25 meter tape in a pre-determined direction opposite from the other diver. The tapes are laid as straight as possible within the same habitat type, with at least a 15 meter distance between each point count. The first count is conducted at the 10 meter mark, and a second count is conducted at 25 meters. If suitable habitat is not present at the designated mark, then the distance is adjusted accordingly. At each survey point, the diver stops and remains still for two minutes, allowing for a settling period. During this time period, the diver records depth, substrate, habitat type, relief, complexity, percent and type of biotic coverage within the area to be surveyed, which is the cylindrical area extending out 5 m from the center point and extending from the substrate to the surface. After the settling period, the diver records the time and begins estimating the number of fish in each five-centimeter size class for all the target species present. The diver has three minutes to allow the fish to naturally redistribute themselves and to list the target species present within the survey cylinder. This time period also allows for cryptic species to reveal themselves for counting.

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. Sampling sites were randomly selected using a one longitudinal by one latitudinal minute grid (approximately $1nm^2$) system. One mile square grids containing areas defined as "Patch Reefs" and "Platform Margin Reefs" were included in the sampling universe, with further random selection of one of 100 "micro-grids" within each selected sampling grid (Figure 2). Within each grid chosen for sampling, a second random selection of one of one hundred 0.1′ x 0.1′ "micro-grids" (~ 0.01 nautical $mile^2$) determined the nominal location within the grid, providing that micro-grid contained reef or patch reef habitat adequate for sampling purposes (Figure 2). If this was not the case, then a randomization procedure was used to relocate the sample to a nearby micro-grid with the desired habitat.

Species sampled

These surveys sampled fifty-four species of commercial and recreational importance members of the following families: Haemulidae (grunts, thirteen species); Serranidae (groupers and sea basses, thirteen species including black grouper); Lutjanidae (snappers, nine species); Chaetodontidae (butterflyfishes, seven species); Balistidae (triggerfishes, three species); Labridae (wrasses, three species); Pomacanthidae (angelfishes, two species) and Priacanthidae (bigeyes, two species).

Unit measure of abundance:

Density (# fish/100 m^2) was used as an index of relative abundance. Density estimates by year, season, strata, and zone were used for spatial comparisons.

Temporal and spatial resolution:

The surveys are conducted from April to October; however, for maximum consistency we only included samples from May through October . Thirty nine randomly selected sites (13 in Zone A, 10 in Zone B, 6 in Zone C and 10 in Zone D) are sampled each month.

Series period:

From 1999 and 2000, the visual survey used two methods: transects and point counts. Since 2001- 2004 and 2007, the program only sampled with visual point counts. For compatibility, only the point counts were included from the 1999 and 2000 sampling. In addition, the 2008 counts were excluded because the FWC visual survey adopted the sampling protocols of the NMFS-UM visual survey in 2008 which uses a 7.5 m diameter imaginary sampling cylinder instead of a 5.0 m diameter imaginary sampling cylinder. The survey was not conducted in 2005 while it underwent a program review.

Indices:

The FWC visual survey index (VS) used the dives conducted from 1999 through 2007. Each dive can be considered a cluster sample and the response variable is the combined total number of a particular fish observed by both divers. In this survey, the spatial extent of a single dive can encompass multiple bottom habitat relief (44% of the dives reported two or more bottom habitat relief categories) and so we used the combined number of fish by species by bottom habitat relief by dive observed by divers as the response variable. There were a total of 2,531 unique dive/habitat combinations and black grouper were observed on 521 of those dive/habitats. The annual nominal point-counts, number per dive/habitat, are shown in Table 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.

However the question remained, were there other dive/habitats that could have seen black grouper but were not? We used an analytical technique to identify which dive/habitats had the potential to observe black grouper. 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 potentially could have seen black 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 eleven species of fish (those with significant regression coefficients at $\alpha = 0.05$) to calculate the probability that the divers could have seen black grouper in their dive/habitats (Table 2, Figure 3).

The threshold for including a dive/habitat was based on the minimum absolute difference between the observed number of dive/habitats and the predicted number of dive/habitats. The range of thresholds was from 0.01 to 0.99 with an initial increment of 0.01. For each threshold value, the number of dive/habitats with probabilities greater than the threshold was tallied (predicted value) and the final threshold was the one with the minimum absolute difference. For the visual survey, the threshold was 0.294 with a predicted number of dive/habitats of 523. However, some of those dives were lacking necessary pieces of information such that there were 520 dive/habitats with complete information.

Once the 520 dive/habitats were selected, we estimated the number of black grouper per dive per habitat by year with a generalized linear model (GLM). Because there were many zero counts of black grouper (319 counts) and the GLM with a Poisson distribution and a log link indicated that the data were over-dispersed (mean deviance = 1.65), 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 black grouper and the second GLM model that used a log-normal distribution with an identity link for the number of black grouper/per point count on those dives that did see black grouper. The potential explanatory variables for the GLM 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 24 m (78.7 ft) combined. Secchi was categorized by two-meter intervals from six or less meters to 26 or more meters (19.7 - 85.3 ft). Variables to include in the model 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 3). The variability was estimated with a Monte Carlo approach that used the least squares means and their standard errors from the GLM for the significant variables identified by AIC. 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, only explained 2.3% of the deviance with zone accounting for 1.2% and the number of point counts (1.1%). The fit was correspondingly noisy (Figure 5). The group of minus residuals in Figure 5b was associated with observations from Zone C with two point-counts. Zone accounted for 4.4% in the model for the number of black grouper seen. Year was not significant in either model meaning that the number of black grouper seen each year was similar and the apparent differences between years were attributable to other factors such as zone or the number of observations (Figure 6). More black grouper were observed in Zones B and C (Figure 7).

As with estimating the MRFSS catch rates (Muller 2009), we 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. Following Kreb's (1999) recommendation for count data, the pair-wise similarities among species were determined with the Morisita similarity measure (vegdist function in the R vegan package, Oksanen 2008). Morisita's index, C_λ, between species *j* and *k* was calculated as

$$C_\lambda = \frac{2\sum X_{ij} X_{ik}}{(\lambda_1 + \lambda_2) N_j N_k}$$

where X_{ij} and X_{ik} are the number of dive/habitat point-counts for species *j* and *k*, N_j is the total number of species *j* and N_k is the total number of species *k*,

$$\lambda_1 = \frac{\sum X_{ij}(X_{ij} - 1)}{N_j(N_j - 1)} \quad \text{and} \quad \lambda_2 = \frac{\sum X_{ik}(X_{ik} - 1)}{N_k(N_k - 1)}.$$

The similarities were then input into a hierarchical cluster model (hclust function in the R stats package, R Development Core Team. 2008) with average linkage clustering.

The other species in the cluster that contained black grouper was Nassau grouper, *Epinephelus striatus* (Figure 8). There were 546 dive/habitats that contained at least one of these species.

The 546 dive/habitats were analyzed with a GLM using a Poisson distribution with a log link. The potential variables were same as those in the S&M proportion positive model except that the dependent variable was now the number of black 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 9) and explained 15.6% of the deviance with depth accounting for 4.4%, zone (4.1%), secchi distance (3.8%), number of point counts in the bottom habitat relief on the dive (1.8%), and year (1.8%) (Table 4).

The catch rates for the visual survey declined from 1999 to 2002 and then increased in 2003 and 2004; the rates for 2006 and 2007 were similar to the earlier lower rates (Table 1 and Figure 10).

Because the visual survey only sampled waters that were 30 m (97 ft) deep or less, they under sampled the deeper reef habitats of the Florida Keys and, as a consequence, they probably missed the larger groupers. Therefore 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. The 95% length range was from 150 mm TL to 800 mm TL and, after rearranging the von Bertalanffy growth equation from Crabtree and Bullock (1998), these lengths correspond to ages 0 through 4.

Therefore, we recommend using the index based on dive/habitats selected by cluster analysis and applying that index to ages 0 through 4.

Literature Cited

Acosta, A. and R. G. Muller. 2008. Annual indices of abundance of mutton snapper for Florida Keys. SEDAR15A-DW-02. National Marine Fisheries Service,. Southeast Fisheries Science Center. Southeast Data, Assessment, and Review. Charleston, SC.

Crabtree, R. E. and L. H. Bullock. 1998. Age, growth, and reproduction of black grouper, *Mycteroperca bonaci*, in Florida waters. Fishery Bulletin 96:735-753.

Krebs, C. J. 1989. Ecological methodology. HarperCollins*Publishers*. New York, N.Y. 654 p.

Lo, N. C., L. D. Jacobson, and J. L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Sciences 49:2515-2526.

Mueter, F. J. and B. L. Norcross. 2000. Changes in species composition of the demersal fish community in nearshore waters of Kodiak Island, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 57:1169-1180.

Muller, R. G. 2009. Black grouper standardized catch rates from the Marine Recreational Fisheries Statistics Survey in south Florida, 1991-2008. SEDAR19-DW-01. National Marine Fisheries Service,. Southeast Fisheries Science Center. Southeast Data, Assessment, and Review. Charleston, SC.

Oksanen, J., R. Kindt, P. Legendre, B. O'Hara, G. L. Simpson, P. Solymos, M. H. H. Stevens and H. Wagner. 2008. vegan: Community Ecology Package. R package version 1.15-1. http://cran.r-project.org/

R Development Core Team. 2008. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. URL http://www.R-project.org.

Rooper. C. N. 2008. An ecological analysis of rockfish (Sebastes spp.) assemblages in the North Pacific Ocean along broad-scale environmental gradients. Fishery Bulletin 106:1-11.

Shertzer, K. W. and E. H. Williams. 2008. Fish assemblages and indicator species: reef fishes off the southeastern United States. Fishery Bulletin 106:257-269.

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

Table 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 black grouper.

		Nominal				Stephens and MacCall				Cluster Analysis		
	Number of	Mean number	Coefficient	Scaled to	Number of	Mean number	Coefficient	Scaled to	Number of	Mean number	Coefficient	Scaled to
Year	dive/habitats	per dive/habitat	of variation	Mean	dive/habitats	per dive/habitat	of variation	Mean	dive/habitats	per dive/habitat	of variation	Mean
1999	47	2.021	0.149	1.19	16	0.195	0.373	1.13	48	1.837	0.133	1.20
2000	58	1.448	0.112	0.85	19	0.186	0.428	1.08	57	1.542	0.135	1.01
2001	79	1.709	0.094	1.01	34	0.171	0.345	1.00	82	1.529	0.116	1.00
2002	80	1.488	0.067	0.88	31	0.168	0.322	0.98	80	1.277	0.093	0.84
2003	60	1.800	0.106	1.06	22	0.166	0.442	0.97	64	1.563	0.125	1.03
2004	57	2.123	0.296	1.25	21	0.159	0.345	0.93	63	1.871	0.104	1.23
2005												
2006	66	1.470	0.083	0.87	28	0.168	0.363	0.98	74	1.240	0.108	0.81
2007	74	1.703	0.073	1.00	30	0.173	0.348	1.00	78	1.532	0.109	1.00

Table 2. Logistic regression coefficients and their standard errors for species associated with black grouper.

			Regression	
NODC Code	Scientific name	Common name	Coefficient	Std Err
		Intercept	-2.9116	0.1459
8839010901	*Lachnolaimus maximus*	Hogfish	0.4009	0.1133
8835360401	*Ocyurus chrysurus*	Yellowtail snapper	0.4161	0.1126
8835550401	*Pomacanthus arcuatus*	Gray angelfish	0.2562	0.1083
8835550101	*Chaetodon ocellatus*	Spotfin butterflyfish	0.3180	0.1074
8835400306	*Anisotremus virginicus*	Porkfish	0.4311	0.1182
8835400113	*Haemulon sciurus*	Bluestriped grunt	0.3552	0.1233
8835360102	*Lutjanus griseus*	Gray snapper	0.3925	0.1193
8835020439	*Cephalopholis cruentata*	Graysby	0.4573	0.1216
8835360103	*Lutjanus analis*	Mutton snapper	0.3099	0.1197
8839010302	*Bodianus rufus*	Spanish hogfish	0.4598	0.1229
8835020412	*Epinephelus striatus*	Nassau grouper	0.7711	0.3041

Table 3a. Step-wise identification of variables to include in the general linearized 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	519	693.8615	1.3369				-346.931			1		695.86
Year	512	690.8190	1.3493	-0.0124	-0.93%		-345.410	-1.521	3.042	7	0.881052	706.82
Month	514	688.7592	1.3400	-0.0031	-0.23%		-344.380	-2.551	5.102	5	0.403535	700.76
Zone	516	681.6256	1.3210	0.0159	1.19%	1.19%	-340.813	-6.118	12.236	3	0.006618	689.63
BottomHabitatRelief	517	693.7132	1.3418	-0.0049	-0.37%		-346.857	-0.074	0.148	2	0.928579	699.71
BottomHabitatType	517	692.4427	1.3393	-0.0024	-0.18%		-346.221	-0.709	1.419	2	0.491988	698.44
Biocover	513	688.4363	1.3420	-0.0051	-0.38%		-344.218	-2.712	5.425	6	0.490567	702.44
Dep_cat	513	691.4955	1.3479	-0.0110	-0.82%		-345.748	-1.183	2.366	6	0.883153	705.50
Secchi	512	686.6981	1.3412	-0.0043	-0.32%		-343.349	-3.582	7.163	7	0.412067	702.70
Num counts	516	681.9896	1.3217	0.0152	1.14%		-340.995	-5.936	11.872	3	0.007835	689.99
With zone												
Year	509	679.0761	1.3341	-0.0131	-0.98%		-339.538	-1.275	2.550	7	0.923316	701.08
Month	511	676.3806	1.3236	-0.0026	-0.19%		-338.190	-2.623	5.245	5	0.386718	694.38
BottomHabitatRelief	514	680.4577	1.3238	-0.0028	-0.21%		-340.229	-0.584	1.168	2	0.557663	692.46
BottomHabitatType	514	679.9621	1.3229	-0.0019	-0.14%		-339.981	-0.832	1.664	2	0.435265	691.96
Biocover	510	676.6504	1.3268	-0.0058	-0.43%		-338.325	-2.488	4.975	6	0.546998	696.65
Dep_cat	510	680.0386	1.3334	-0.0124	-0.93%		-340.019	-0.793	1.587	6	0.953507	700.04
Secchi	509	671.1917	1.3186	0.0024	0.18%		-335.596	-5.217	10.434	7	0.165284	693.19
Num counts	513	670.3316	1.3067	0.0143	1.07%	2.26%	-335.166	-5.647	11.294	3	0.010238	684.33
With zone and num_divers												
Year	506	666.4834	1.3172	-0.0105	-0.79%		-333.242	-1.924	3.848	7	0.797086	694.48
Month	508	664.8499	1.3088	-0.0021	-0.16%		-332.425	-2.741	5.482	5	0.359968	688.85
BottomHabitatRelief	511	667.9813	1.3072	-0.0005	-0.04%		-333.991	-1.175	2.350	2	0.308757	685.98
BottomHabitatType	511	667.4609	1.3062	0.0005	0.04%		-333.730	-1.435	2.871	2	0.23802	685.46
Biocover	507	665.3147	1.3123	-0.0056	-0.42%		-332.657	-2.508	5.017	6	0.54166	691.31
Dep_cat	507	668.9631	1.3195	-0.0128	-0.96%		-334.482	-0.684	1.369	6	0.967741	694.96
Secchi	506	658.0846	1.3006	0.0061	0.46%		-329.042	-6.123	12.247	7	0.092723	686.08

Table 3b. Step-wise identification of variables to include in the general linearized model (log-normal distribution and identity link) for the number of black 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 dev	% mean dev	Cum %	log like	Δ log like	-2*log like	df X^2	Prob Ho	AIC
Null	200	80.7466	0.4037				-193.552			2		391.10
Year	193	77.9874	0.4041	-0.0004	-0.10%		-190.058	-3.494	6.989	7	0.430068	398.12
Month	195	79.6163	0.4083	-0.0046	-1.14%		-192.135	-1.417	2.834	5	0.725621	398.27
Zone	197	76.0211	0.3859	0.0178	4.41%	4.41%	-187.491	-6.061	12.121	3	0.006979	384.98
BottomHal	198	79.2205	0.4001	0.0036	0.89%		-191.634	-1.918	3.835	2	0.146945	391.27
BottomHal	198	80.6606	0.4074	-0.0037	-0.92%		-193.445	-0.107	0.214	2	0.898346	394.89
Biocover	194	80.0456	0.4126	-0.0089	-2.20%		-192.676	-0.876	1.753	6	0.940989	401.35
Dep_cat	194	78.9738	0.4071	-0.0034	-0.84%		-191.321	-2.231	4.462	6	0.614387	398.64
Secchi	193	77.9711	0.4040	-0.0003	-0.07%		-190.037	-3.515	7.031	7	0.425701	398.07
With zone												
Year	190	73.2590	0.3856	0.0003	0.07%		-183.772	-3.719	7.439	7	0.384644	391.54
Month	192	75.3804	0.3926	-0.0067	-1.66%		-186.640	-0.851	1.701	5	0.888723	393.28
BottomHal	195	74.2596	0.3808	0.0051	1.26%		-185.135	-2.356	4.712	2	0.094789	384.27
BottomHal	195	75.9863	0.3897	-0.0038	-0.94%		-187.445	-0.046	0.092	2	0.954946	388.89
Biocover	191	75.3373	0.3944	-0.0085	-2.11%		-186.583	-0.908	1.816	6	0.935803	395.17
Dep_cat	191	74.8598	0.3919	-0.0060	-1.49%		-185.944	-1.547	3.094	6	0.796934	393.89
Secchi	190	73.2851	0.3857	0.0002	0.05%		-183.807	-3.684	7.367	7	0.391654	391.61

Table 4. Step-wise identification of variables to include in the general linearized model (Poisson distribution with a log link) for the number of black 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 dev	Cum %	log like	Δ log like	-2*log like	df X^2	Prob Ho	AIC
Null	545	598.4081	1.0980				-459.017			2		922.03
Year	538	584.3697	1.0862	0.0118	1.07%		-451.997	-7.019	14.038	7	0.050506	921.99
Month	540	589.6026	1.0919	0.0061	0.56%		-454.614	-4.403	8.805	5	0.117082	923.23
Zone	542	570.5144	1.0526	0.0454	4.13%	4.13%	-445.070	-13.947	27.894	3	3.82E-06	900.14
BottomHabitatRelief	543	592.9380	1.0920	0.0060	0.55%		-456.282	-2.735	5.470	2	0.064894	920.56
BottomHabitatType	543	596.6929	1.0989	-0.0009	-0.08%		-458.159	-0.858	1.715	2	0.424179	924.32
Biocover	539	580.2593	1.0765	0.0215	1.96%		-449.942	-9.074	18.149	6	0.005871	915.88
Dep_cat	539	565.0412	1.0483	0.0497	4.53%		-442.333	-16.683	33.367	6	8.91E-06	900.67
Secchi	535	563.4611	1.0532	0.0448	4.08%		-441.543	-17.473	34.947	10	0.000128	907.09
Num_counts	542	577.4074	1.0653	0.0327	2.98%		-448.516	-10.500	21.001	3	0.000105	907.03
With zone												
Year	535	558.2630	1.0435	0.0091	0.83%		-438.944	-6.126	12.251	7	0.092589	901.89
Month	537	562.5956	1.0477	0.0049	0.45%		-441.110	-3.959	7.919	5	0.160768	902.22
BottomHabitatRelief	540	568.0769	1.0520	0.0006	0.05%		-443.851	-1.219	2.437	2	0.295614	901.70
BottomHabitatType	540	568.9857	1.0537	-0.0011	-0.10%		-444.305	-0.764	1.529	2	0.46566	902.61
Biocover	536	554.7019	1.0349	0.0177	1.61%		-437.163	-7.906	15.813	6	0.014796	896.33
Dep_cat	536	538.4473	1.0046	0.0480	4.37%	8.51%	-429.036	-16.034	32.067	6	1.58E-05	880.07
Secchi	532	540.2921	1.0156	0.0370	3.37%		-429.959	-15.111	30.222	10	0.000788	889.92
Num_counts	539	555.7994	1.0312	0.0214	1.95%		-437.712	-7.358	14.715	3	0.002077	891.42
With zone and depth category												
Year	529	522.4064	0.9875	0.0171	1.56%		-421.016	-8.020	16.041	7	0.024746	878.03
Month	531	531.2442	1.0005	0.0041	0.37%		-425.435	-3.601	7.203	5	0.205975	882.87
BottomHabitatRelief	534	536.1853	1.0041	0.0005	0.05%		-427.905	-1.131	2.262	2	0.322743	881.81
BottomHabitatType	534	536.3415	1.0044	0.0002	0.02%		-427.983	-1.053	2.106	2	0.348959	881.97
Biocover	530	519.5836	0.9803	0.0243	2.21%		-419.604	-9.432	18.864	6	0.0044	873.21
Secchi	526	506.1988	0.9624	0.0422	3.84%	12.35%	-412.912	-16.124	32.248	10	0.000364	867.82
Num_counts	533	524.2607	0.9836	0.0210	1.91%		-421.943	-7.093	14.187	3	0.002662	871.89
With zone, depth category, and secchi												
Year	519	490.4696	0.9450	0.0174	1.58%		-405.047	-7.865	15.729	7	0.027709	866.09
Month	521	498.6372	0.9571	0.0053	0.48%		-409.131	-3.781	7.562	5	0.182109	870.26
BottomHabitatRelief	524	504.3291	0.9625	-0.0001	-0.01%		-411.977	-0.935	1.870	2	0.392625	869.95
BottomHabitatType	524	505.1655	0.9641	-0.0017	-0.15%		-412.395	-0.517	1.033	2	0.596486	870.79
Biocover	520	492.3683	0.9469	0.0155	1.41%	13.76%	-405.997	-6.915	13.830	6	0.031589	865.99
Num_counts	523	492.7940	0.9422	0.0202	1.84%		-406.210	-6.702	13.405	3	0.003838	860.42
With zone, depth category, secchi, and num_counts												
Year	516	476.0360	0.9226	0.0196	1.79%	15.55%	-397.831	-8.379	16.758	7	0.019025	857.66
Month	518	486.8675	0.9399	0.0023	0.21%		-403.246	-2.963	5.926	5	0.313447	864.49
BottomHabitatRelief	521	491.8783	0.9441	-0.0019	-0.17%		-405.752	-0.458	0.916	2	0.632611	863.50
BottomHabitatType	521	490.8961	0.9422	0.0000	0.00%		-405.261	-0.949	1.898	2	0.387128	862.52
Biocover	517	478.2244	0.9250	0.0172	1.57%		-398.925	-7.285	14.570	6	0.023882	857.85
With zone, depth category, secchi, num_counts, and year												
Month	511	470.7850	0.9213	0.0013	0.12%		-395.205	-2.625	5.251	5	0.386022	868.41
BottomHabitatRelief	514	475.3526	0.9248	-0.0022	-0.20%		-397.489	-0.342	0.683	2	0.710561	866.98
BottomHabitatType	514	473.5661	0.9213	0.0013	0.12%		-396.596	-1.235	2.470	2	0.290864	865.19
Biocover	510	461.7898	0.9055	0.0171	1.56%		-390.707	-7.123	14.246	6	0.027004	861.41

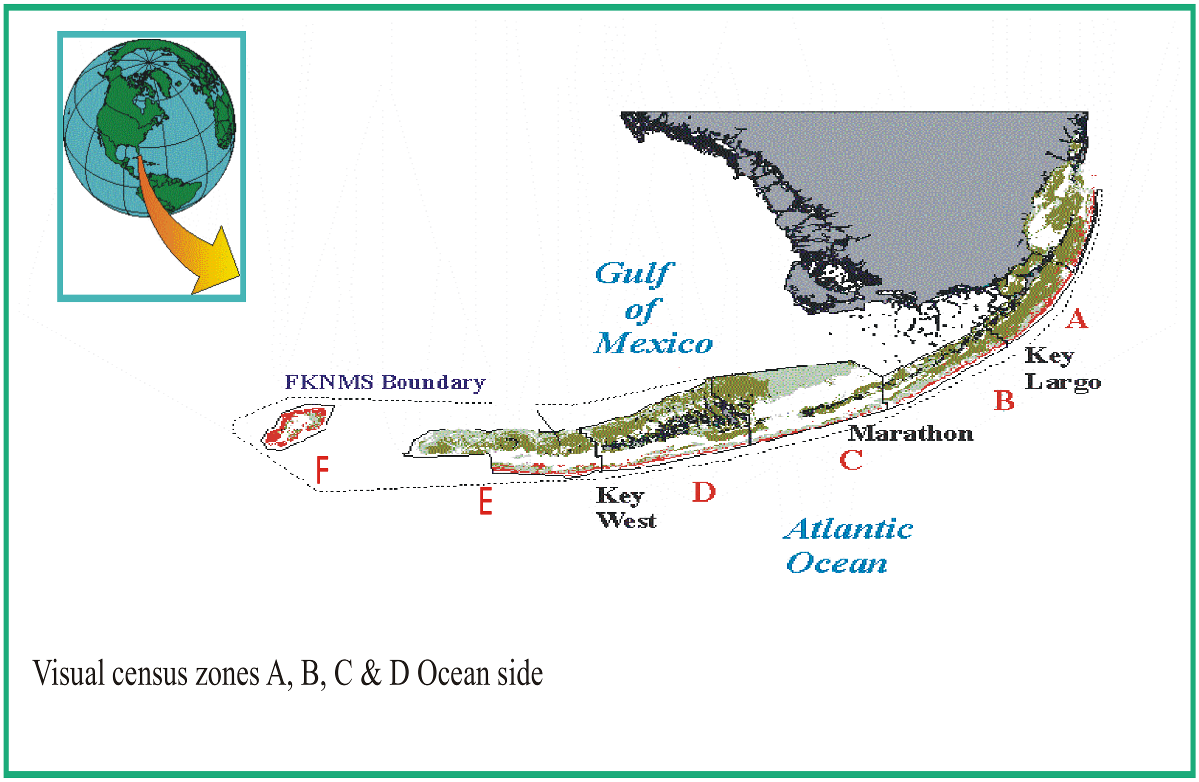


Figure 1. Map of Fisheries-Independent Monitoring Program sampling areas, divided into 4 zones (A-D), in the Florida Keys National Marine Sanctuary (FKNMS).

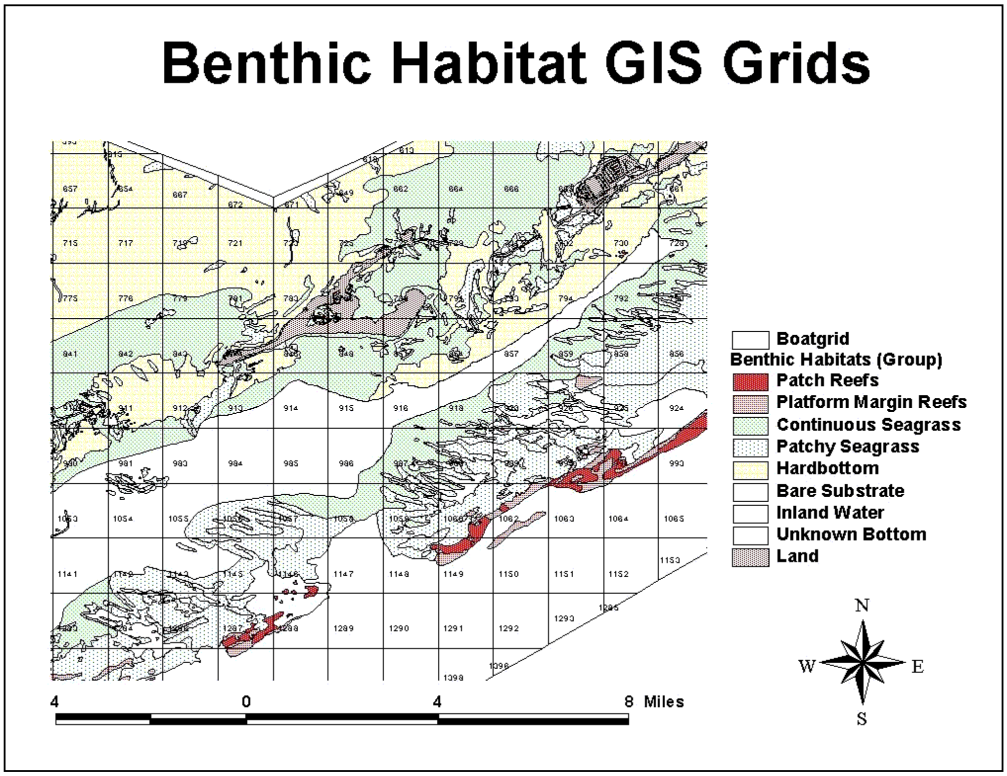


Figure 2. A habitat-based, random-stratified site selection procedure, based upon the "Benthic Habitats of the Florida Keys" GIS system.

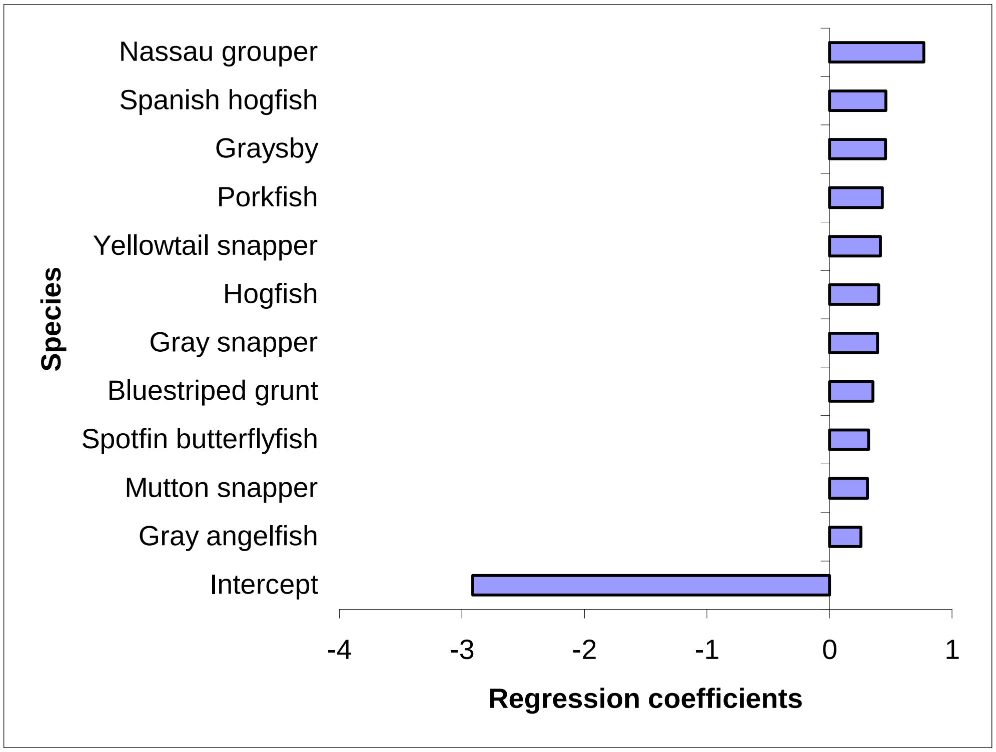


Figure 3. Species with significant regression coefficients for calculating the threshold for whether a dive/habitat should be selected for inclusion in calculating the index.

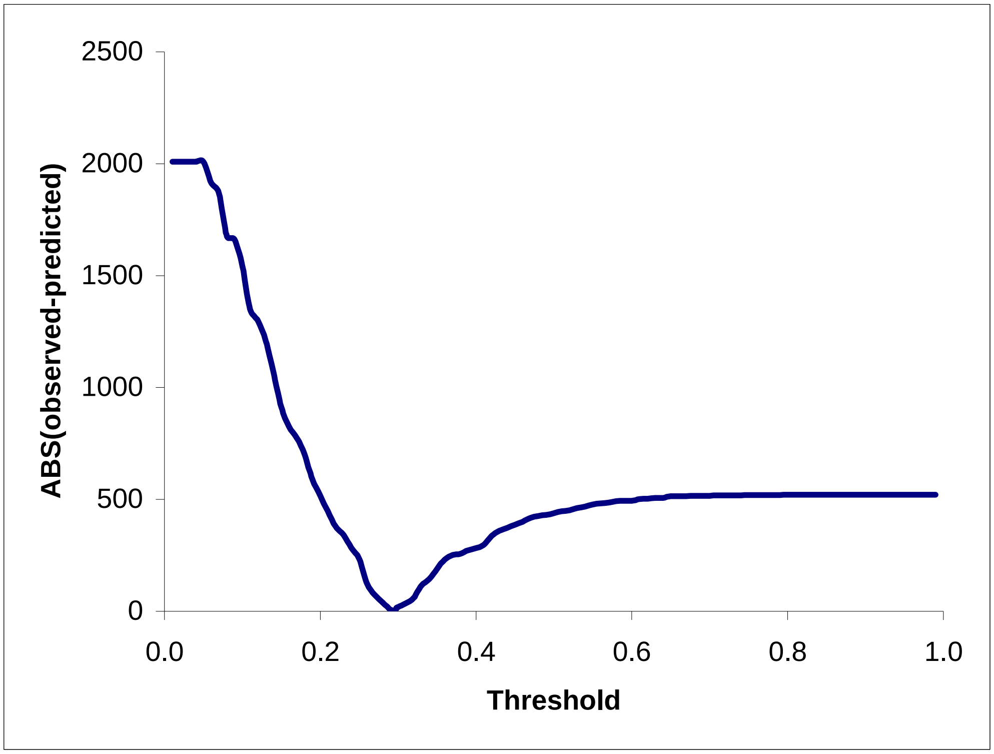
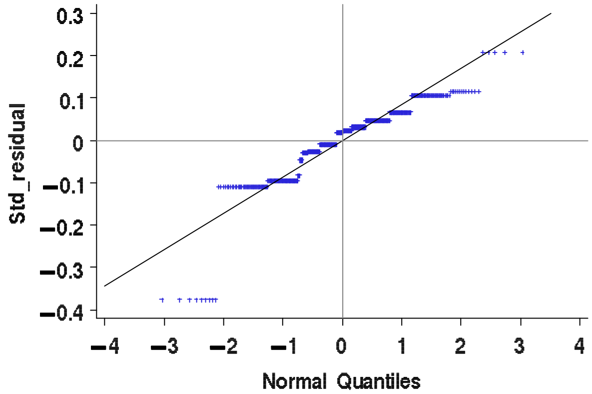
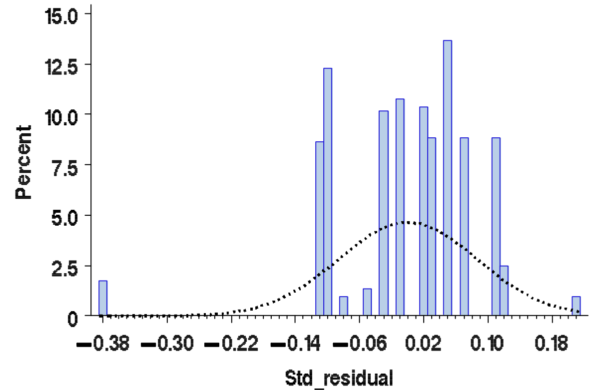


Figure 4. The absolute differences between observed and predicted dives per habitat for black grouper by critical value from Stephens and MacCall's regression.

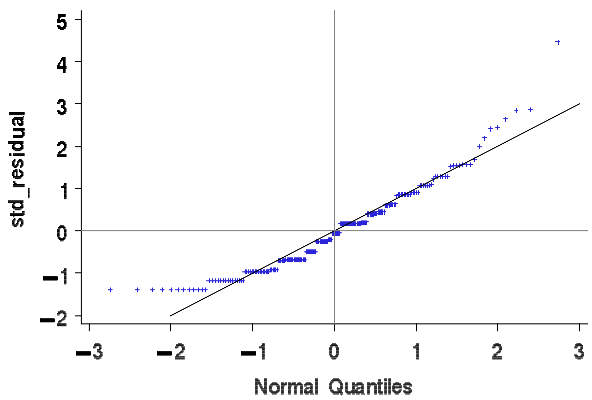
a.



b.



c.



d.

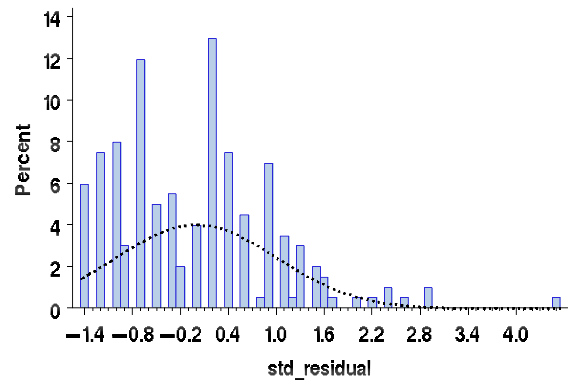


Figure 5. Quantile plot (a) and standardized residuals (b) of the generalized linear model (GLM) using a binomial distribution with a logit link for the proportion of positive intercepts and a quantile plot (c) and standardized residuals (d) of the GLM using a log-normal distribution with an identity 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..

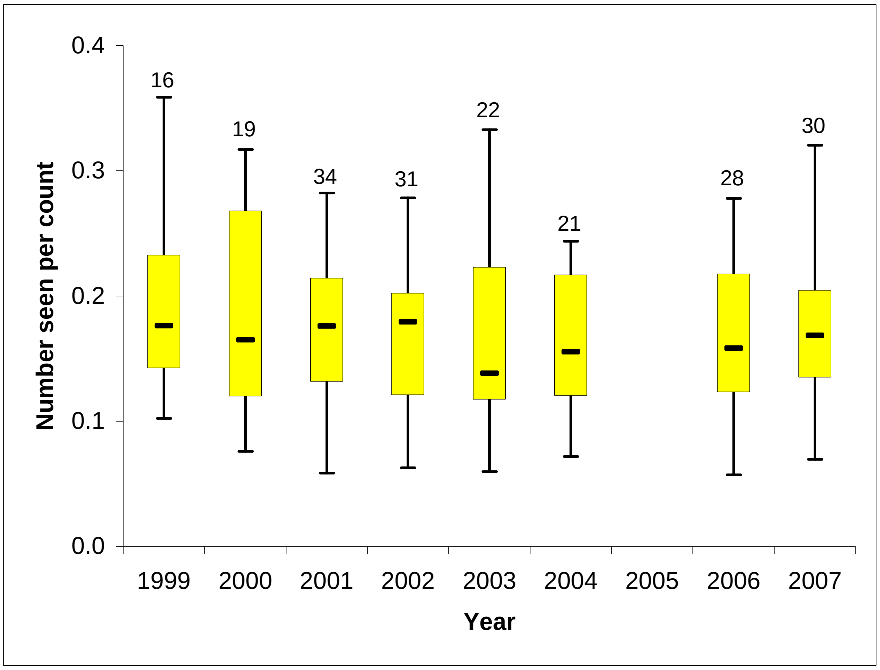


Figure 6. The estimated number of black grouper per dive/habitat point-count by year observed by the visual survey. Vertical line – 95% confidence interval, box – inter-quartile range, horizontal line – median, and the number is the number of dive/habitats.

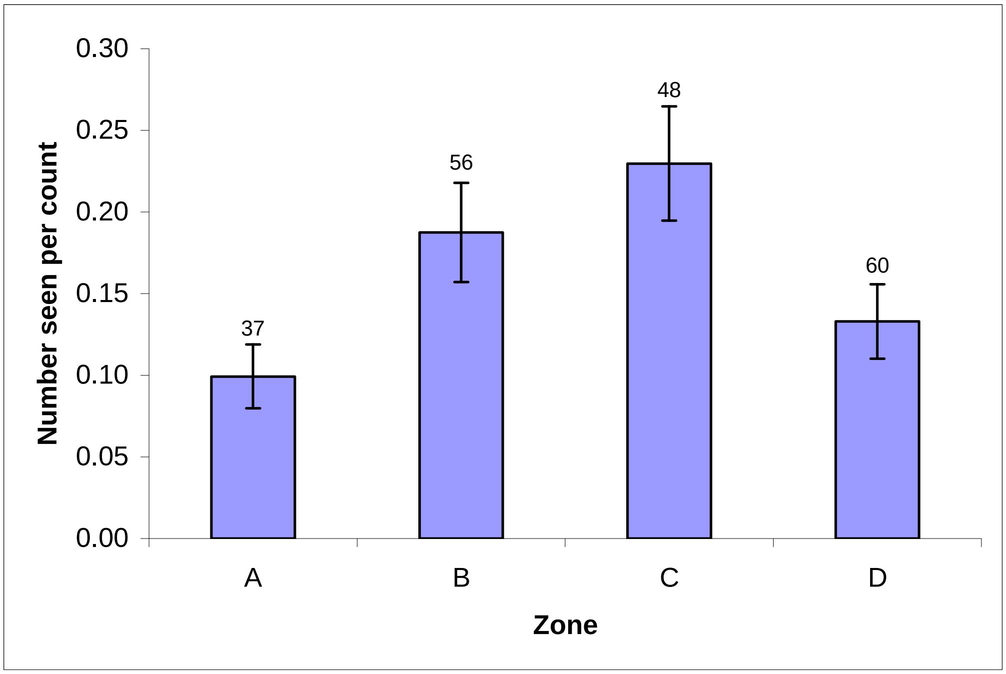


Figure 7. Number of black grouper per dive/habitat point-count by zone observed by the visual survey. Vertical line – 95% confidence interval, box – inter-quartile range, horizontal line – median, and the number is the number of dive/habitats.

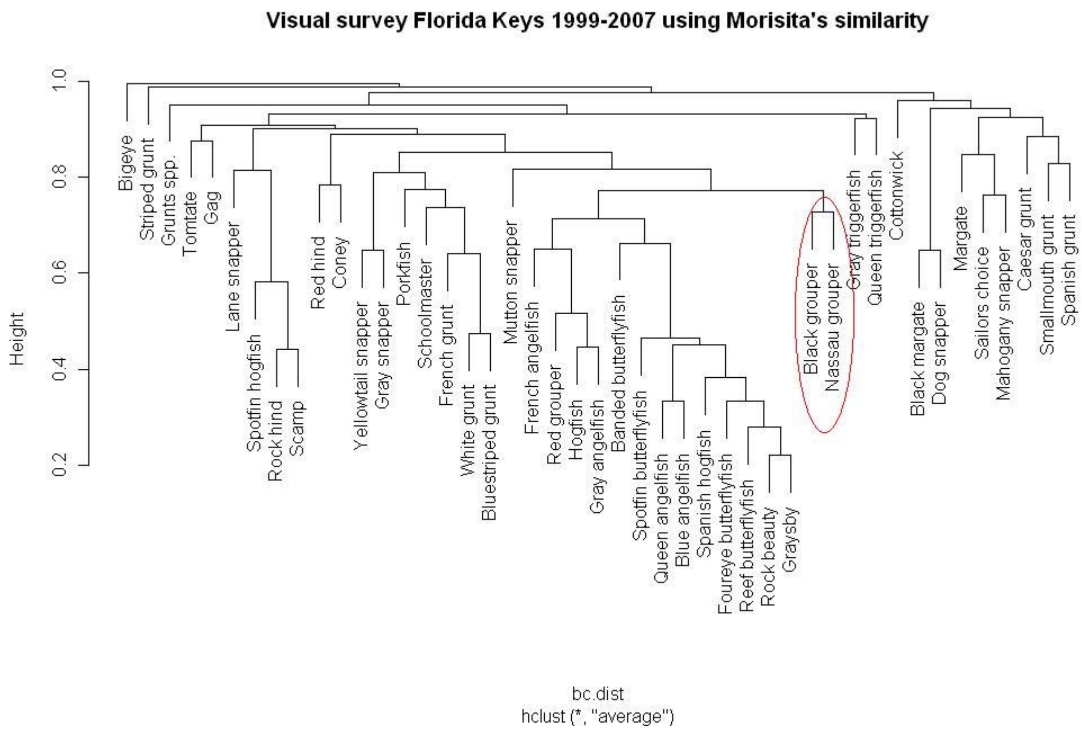
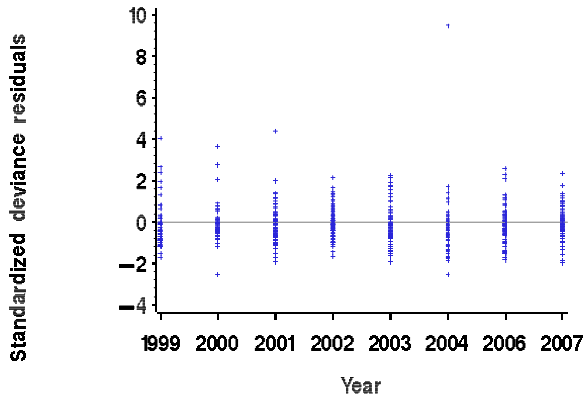
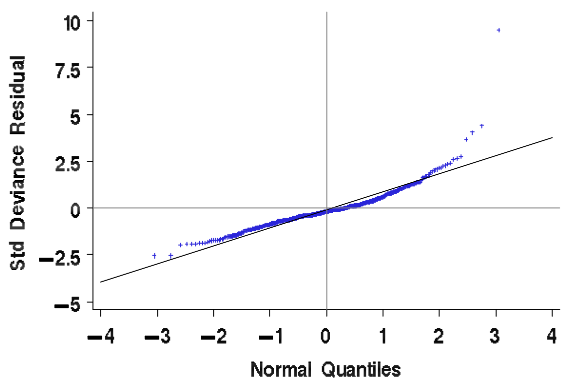


Figure 8. Species clusters identified with hierarchical cluster analysis of pair-wise similarity of species for visual survey data. The cluster with black grouper is indicated by the ellipse.

a.



b.



c.

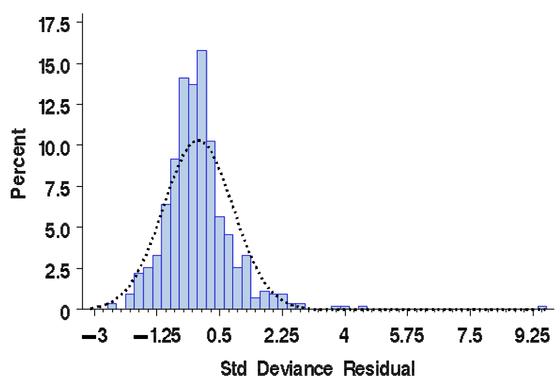


Figure 9. Standardized residuals by year (a), quantile plot (b) and the distribution of the standardized residuals (c) from the GLM using a Poisson distribution with a log link for the number of black grouper observed per dive/habitat selected with cluster analysis.

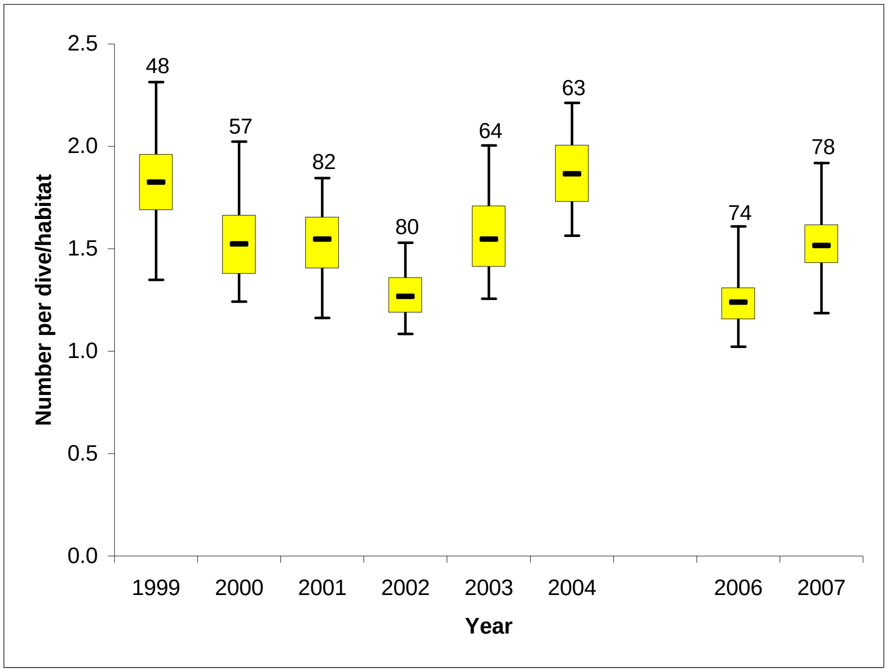


Figure 10. The estimated number of black grouper per dive per bottom habitat by year observed by the visual survey estimated from dive/habitat point-counts selected by cluster analysis. Vertical line – 95% confidence interval, box – inter-quartile range, horizontal line – median, and the number is the number of dive/habitats.