Standardized Reef Fish Visual Census index for the Florida reef track from Biscayne Bay through Florida Keys for 1997-2014

Robert G. Muller

SEDAR48-DW-03

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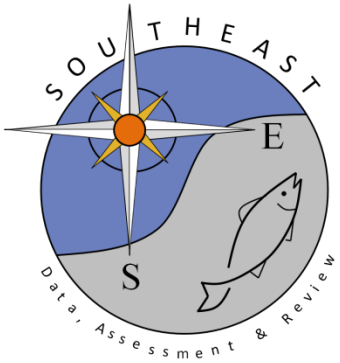

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Introduction

The Reef fish Visual Census (RVC) began in 1979 with SCUBA divers counting fish along the Florida reef track following a two-stage stratified random survey design (Bohnsack and Bannerot 1986; Bohnsack et *al.* 1999; and Ault et *al.* 2001). They created a list of habitat sampling strata by dividing the Florida reef track into 200 m x 200 m blocks and tallying the habitats in each block. Annually (biennially after 2012), block are randomly selected by habitat and then divers (usually two) are deployed at each of two randomly located stations within the block. The divers identify and count the fish within an imaginary cylinder with a 7.5 m radius. The RVC sampling protocols have evolved over time but have been stable since 1997 when the Florida Keys National Marine Sanctuary set aside Sanctuary Protected Areas (SPAs) which the RVC accommodated by recording whether the station was in a SPA or not. Florida Fish and Wildlife Conservation Commission (FWC) began a similar visual survey in 1999 and the two surveys were combined in 2009.

In its review of fishery stock assessments, the National Research Council, recommended using fishery-independent indices whenever possible (1998) because a fishery independent survey is not affected by regulatory changes such as changes in size limits or trip or bag limits. Although there are other potential sources for fishery independent indices they rarely encounter Black Grouper. For example, NOAA's video survey in the Gulf of Mexico with an average of 200 camera sets per year rarely saw more than one or two Black Grouper in a year (Matthew Campbell, NOAA pers. comm.); FWC-FWRI offshore video and trap survey rarely observe Black Grouper (Ted Switzer, FWC pers. comm.); similarly, FWC's baitfish cruises across the West Florida Shelf have taken only one length measurement for Black Grouper (Keith Fischer FWC FWRI, pers. comm.). The Reef Fish Visual Census (RVC) is the only fishery-independent source that could be used to develop a fishery independent index for Black Grouper

In SEDAR 19, Ingram and Harper (2009) developed separate indices for the Florida Keys (1979-2007) and for the Dry Tortugas (1994-2008) although the Dry Tortugas was only sampled intermittently. With the institution of the Florida Keys National Marine Sanctuary and the establishment of Sanctuary Protected Areas, RVC personnel recommended only using data from 1997 and later for consistency with their revised and improved sampling design.

Methods

I extracted the RVC station point count data for the Florida Keys for the 1997-2014 time period; there was no sampling in 2013 due to the biennial sampling schedule and the 2016 data will be available in late March 2017. The 1997 and 1998 data lacked three fields when compared to the later data (whether the dive location was in a SPA, the stratum being sampled based on zone and habitat, and region which was based on the subregion of the Florida Keys) but these fields could be constructed from other reported information. Additional data filtering included deleting the experimental winter surveys that were conducted in 2004/2005, accepting only stations with underwater visibility of 7.5 m or greater, and

removing stations that were conducted in sand, seagrass, mud, or artificial habitats because these habitats were not part of the RVC domain. The basic observation is the average number of fish observed by the divers at a station. Additional surveys have been conducted in the waters surrounding the Dry Tortugas National Park in some years but those stations were not included in these analyses. The final dataset consisted of 8,450 station samples.

Similar to the approach that Ingram and Harper (2009) used, the index was standardized with the hurdle approach which splits the process into two generalized linear submodels (Lo *et al.* 1992): a submodel to estimate the proportion of positive stations with a binomial distribution that used a logit link and a submodel to estimate the mean number of Black Grouper caught at a positive station with a gamma distribution also using a log link. Ingram and Harper used a Poisson distribution for the number of Black Grouper observed at positive stations. I evaluated Poisson and the lognormal distributions as well as the gamma distribution for the number of Black Grouper observed at positive stations and the selection of the distribution in the final configuration was based on the extent of the reduction in the mean deviance. The annual index is the product of the proportion of positive stations (***Prop***) and the mean number of Black Grouper seen per station ($\hat{\boldsymbol{Y}}$) 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 $\hat{Y} = e^{g(x1+x2+...)}$ where the *x1, x2,…* refer to the variables included in the final, respective linear submodels).

Potential explanatory variables included year (1997 to 2014), season (Apr-Jun, Jul-Sep, Oct-Dec), sub-regions of the reef track (Biscayne, Upper Keys, Middle Keys, Lower Keys), Sanctuary Protected Area (yes, no), strata (inshore patch reef, mid-channel patch reef, offshore patch reef, high relief reef, shallow forereef, mid-depth forereef , deep forereef), depth (5m categories with 25 m +), and underwater visibility (5m categories with 20 m +). All of the potential, explanatory variables were treated as categorical variables partially to account for non-linearity.

The submodels used a forward stepwise process starting with the null model to identify which variables should be included in the respective submodels. Variables to be included in the final submodel, had to meet two criteria: the variable had to be statistically significant at the 0.05 level (the probability of rejecting the null hypothesis) and its inclusion had to reduce the deviance (a measure of the variability) by at least 0.5%.

To calculate the variability in the annual indices, I used a Monte Carlo simulation approach with 10,000 iterations that used the least-squares mean estimates and their standard errors from the two GLIM submodels. Each iteration used the annual least-squares mean estimate on the linear scale 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 scales and multiplied together.

Results and Discussion

The submodel estimating the probability that a Black Grouper was observed at a station reduced the deviance by 12.1% and the variables in the final submodel listed in decreasing order of importance included the subregions of the reef track, habitat strata, year, whether the station was in a protected area, and the depth category (Table 1). Diagnostic plots for the probability of seeing a Black Grouper at

a station submodel is shown in Fig. 1. The submodel estimating the number of Black Grouper observed at successful stations with the gamma distribution reduced the deviance by 10.9% (Poisson distribution 6.9% and the log-normal distribution 7.5%), and the variables in the final submodel, also listed in decreasing order of importance, included year, depth category, whether the station was in a protected area, subregions of the reef track, and habitat strata (Table 2). A residual plot of the probability of seeing a Black Grouper at the station submodel is shown in Fig.1. A gamma distribution for the positive stations submodel was selected for constructing the index because of its slightly larger reduction in deviance compared with the Poisson and lognormal submodels.

The Reef Fish Visual Census index was stable but variable from 1997 until 2005 and then declined to a lower level with high values in 2011 and a low value in 2014 (Table 3, Fig. 2). The coefficients of variation were reasonable ranging from 0.086 to 0.208. The nominal index had a similar shape as the standardized RVC index (Fig. 3).

Although the reviewers for SEDAR 19, recommended only using the age-1 index from FWC, the change of assessment models now allows using a length-based selectivity instead of age-based (Fig. 4). Being a non-destructive sampling method, the RVC does not collect any age information; thus in SEDAR 19, the fish's length had to be converted to age using an age-length key from different sources which introduced additional uncertainty into the analyses. Therefore, the change in assessment models means that the RVC index can include all of the Black Grouper observed during the surveys instead of just those Black Grouper with lengths believed to represent age-1. Because the Black Grouper observed by the divers at the depths sampled (1 to 33 m) were mostly sub-adults (only about 3% were at or greater than the total length at which 50% of the female fish were mature (82.6 cm), this index should use a length-based dome-shaped selectivity curve.

Being the only fishery-independent index available for Black Grouper, this index should be useful in the assessment; however, it must be remembered that this index, based on stations in shallow waters, is a primarily a sub-adult index and does not provide guidance on adult fish or spawning biomass

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Table 1. Stepwise selection of variables to include in estimating the proportion of positive Reef Fish Visual Census stations (shaded lines) with a GLM (binomial distribution and logit 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
	8449	8183.72	0.96860	.	.	.	.	Conv	
subregion_nr	8446	7849.02	0.92932	3	334.70	0.00000	4.06	Conv	4.06
strat	8443	7873.26	0.93252	6	310.45	0.00000	3.73	Conv	
depth_cat	8439	7987.7	0.94652	10	196.02	0.00000	2.28	Conv	
prot	8448	8018.43	0.94915	1	165.29	0.00000	2.01	Conv	
year	8433	8074.47	0.95749	16	109.25	0.00000	1.15	Conv	
visibility_cat	8444	8163.75	0.96681	5	19.96	0.00127	0.19	Conv	
season	8447	8178.46	0.96821	2	5.25	0.07229	0.04	Conv	
subregion_nr	8446	7849.02	0.92932	.	.	.	.	Conv	
subregion_nr strat	8440	7536.93	0.89300	6	312.09	0.00000	3.75	Conv	7.81
subregion_nr depth_cat	8436	7658.25	0.90781	10	190.77	0.00000	2.22	Conv	
subregion_nr year	8430	7707.32	0.91427	16	141.70	0.00000	1.55	Conv	
subregion_nr prot	8445	7785.61	0.92192	1	63.41	0.00000	0.76	Conv	
subregion_nr visibility_cat	8441	7819.45	0.92637	5	29.57	0.00002	0.31	Conv	
subregion_nr season	8444	7834.24	0.92779	2	14.78	0.00062	0.16	Conv	
subregion_nr strat	8440	7536.93	0.89300	.	.	.	.	Conv	
subregion_nr strat year	8424	7364.23	0.87420	16	172.71	0.00000	1.94	Conv	9.75
subregion_nr strat depth_cat	8430	7413.52	0.87942	10	123.41	0.00000	1.40	Conv	
subregion_nr strat prot	8439	7435.94	0.88114	1	100.99	0.00000	1.23	Conv	
subregion_nr strat visibility_cat	8435	7510.58	0.89041	5	26.35	0.00008	0.27	Conv	
subregion_nr strat season	8438	7528.55	0.89222	2	8.38	0.01513	0.08	Conv	

Table 1 continued. Stepwise selection of variables to include in estimating the proportion of positive Reef Fish Visual Census stations (shaded lines) with a GLM (binomial distribution and logit 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
subregion_nr strat year	8424	7364.23	0.874196	.	.	.	.	Conv	
subregion_nr strat year prot	8423	7248.26	0.860532	1	115.9642	0	1.411	Conv	11.2
subregion_nr strat year depth_cat	8414	7268.12	0.863812	10	96.10895	0	1.072	Conv	
subregion_nr strat year visibility_cat	8419	7351.35	0.873185	5	12.88151	0.0245148	0.104	Conv	
subregion_nr strat year season	8422	7360.78	0.873994	2	3.44694	0.178446	0.021	Conv	
subregion_nr strat year prot	8423	7248.26	0.860532	.	.	.	.	Conv	
subregion_nr strat year prot depth_cat	8413	7160.97	0.851179	10	87.29291	0	0.966	Conv	12.1
subregion_nr strat year prot visibility_cat	8418	7238.37	0.859868	5	9.8922	0.078348	0.069	Conv	
subregion_nr strat year prot season	8421	7243.13	0.860127	2	5.13125	0.0768711	0.042	Conv	
subregion_nr strat year prot depth_cat	8413	7160.97	0.851179	.	.	.	.	Conv	
subregion_nr strat year prot depth_cat season	8411	7155.32	0.85071	2	5.65015	0.0593043	0.048	Conv	
subregion_nr strat year prot depth_cat visibili	8408	7154.32	0.850894	5	6.65299	0.2477534	0.029	Conv	

Table 2. Stepwise selection of variables to include in estimating the number of Black Grouper observed at positive Reef Fish Visual Census stations (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
	1593	507.53	0.318601	.	.	.	.	Conv	
year	1577	467.99	0.29676	16	135.5217	0	6.855	Conv	6.9
depth_cat	1583	497.13	0.314044	10	34.63899	0.0001439	1.43	Conv	
subregion_nr	1590	499.77	0.314322	3	25.77493	0.0000106	1.343	Conv	
prot	1592	503.78	0.316447	1	12.40036	0.0004293	0.676	Conv	
strat	1587	502.2	0.316449	6	17.65541	0.0071536	0.675	Conv	
season	1591	503.91	0.316723	2	11.99412	0.002486	0.589	Conv	
visibility_cat	1588	506.08	0.31869	5	4.79252	0.441722	-0.028	Conv	
year	1577	467.99	0.29676	.	.	.	.	Conv	
year depth_cat	1567	456.77	0.29149	10	40.47615	0.000014	1.654	Conv	8.5
year subregion_nr	1574	461.32	0.29309	3	23.92869	0.0000259	1.152	Conv	
year strat	1571	462.01	0.294086	6	21.45437	0.0015197	0.84	Conv	
year season	1575	464.8	0.295114	2	11.39683	0.0033513	0.517	Conv	
year prot	1576	465.68	0.29548	1	8.26844	0.004034	0.402	Conv	
year visibility_cat	1572	466.01	0.296443	5	7.08127	0.2146661	0.1	Conv	
year depth_cat	1567	456.77	0.29149	.	.	.	.	Conv	
year depth_cat subregion_nr	1564	449.6	0.287469	3	26.33241	0.0000081	1.262	Conv	9.8
year depth_cat prot	1566	451.73	0.288461	1	18.4661	0.0000173	0.951	Conv	
year depth_cat season	1565	454.31	0.290292	2	8.99183	0.0111545	0.376	Conv	
year depth_cat strat	1561	454.84	0.291377	6	7.04249	0.3169359	0.036	Conv	
year depth_cat visibility_cat	1562	455.63	0.291694	5	4.15974	0.5266538	-0.064	Conv	

Table 2 continued. Stepwise selection of variables to include in estimating the number of Black Grouper observed at positive Reef Fish Visual Census stations (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
year depth_cat subregion_nr	1564	449.6	0.287469	.	.	.	.	Conv	
year depth_cat subregion_nr prot	1563	446.26	0.285513	1	12.43431	0.0004215	0.614	Conv	10.4
year depth_cat subregion_nr season	1562	446.29	0.285716	2	12.31709	0.0021153	0.55	Conv	
year depth_cat subregion_nr strat	1558	447.53	0.287244	6	7.70437	0.2605719	0.071	Conv	
year depth_cat subregion_nr visibility_cat	1559	447.88	0.287286	5	6.38987	0.2701089	0.057	Conv	
year depth_cat subregion_nr prot	1563	446.26	0.285513	.	.	.	.	Conv	
year depth_cat subregion_nr prot season	1561	443.13	0.283876	2	11.70272	0.002876	0.514	Conv	10.9
year depth_cat subregion_nr prot strat	1557	444.3	0.285358	6	7.30237	0.2937866	0.048	Conv	
year depth_cat subregion_nr prot visibility_cat	1558	444.83	0.285515	5	5.31911	0.3781889	-0.001	Conv	
year depth_cat subregion_nr prot season	1561	443.13	0.283876	.	.	.	.	Conv	
year depth_cat subregion_nr prot season strat	1555	441.2	0.28373	6	7.26164	0.2973269	0.046	Conv	
year depth_cat subregion_nr prot season visibility_cat	1556	441.55	0.283773	5	5.9416	0.3119435	0.032	Conv	

Table3. The Reef Fish Visual Census index, its coefficient of variation, the number of stations sampled, the number of stations where Black Grouper were observed, the RVC index scaled to its mean, nominal index, and the nominal index scaled to its mean.

Year	Number per station	Coefficient of variation	Number of stations	Number of stations with Black Grouper	Index scaled to mean	Nominal index	Nominal index scaled to mean
1997	0.074	0.177	408	43	0.328	0.067	0.412
1998	0.107	0.147	461	64	0.474	0.091	0.557
1999	0.163	0.132	440	76	0.720	0.136	0.829
2000	0.284	0.111	513	104	1.257	0.231	1.411
2001	0.252	0.093	742	155	1.116	0.188	1.151
2002	0.426	0.085	578	142	1.882	0.262	1.601
2003	0.245	0.132	300	59	1.083	0.151	0.923
2004	0.356	0.136	208	52	1.573	0.240	1.469
2005	0.313	0.114	358	85	1.385	0.249	1.519
2006	0.192	0.139	404	59	0.850	0.126	0.771
2007	0.233	0.116	494	91	1.031	0.170	1.039
2008	0.192	0.105	635	111	0.848	0.132	0.803
2009	0.127	0.111	829	113	0.564	0.096	0.586
2010	0.183	0.116	554	91	0.808	0.133	0.811
2011	0.324	0.082	643	175	1.432	0.239	1.459
2012	0.227	0.099	543	118	1.003	0.159	0.973
2013							
2014	0.201	0.140	340	56	0.887	0.142	0.898

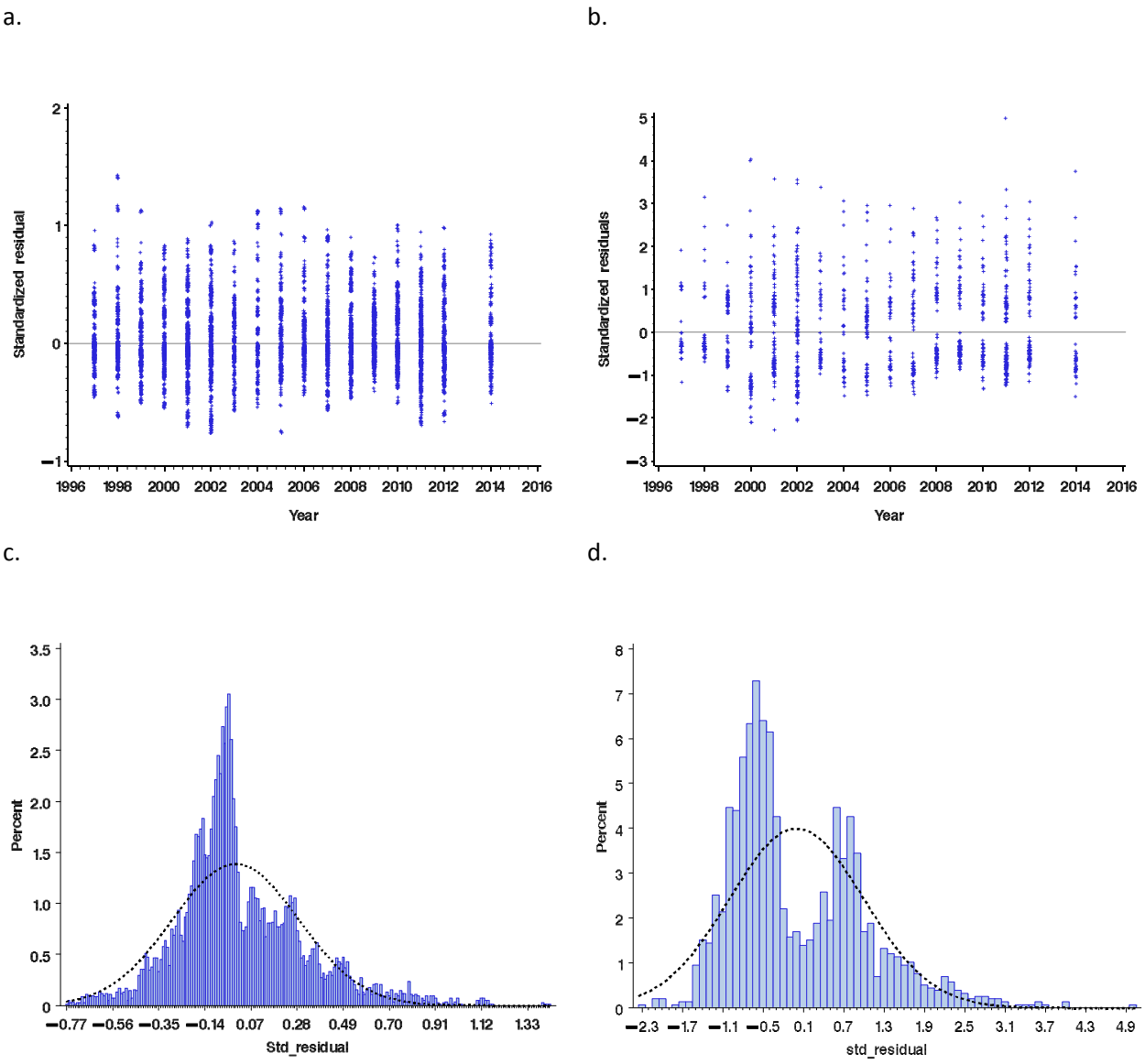

Figure 1. Diagnostic plots for the probability fit using a binomial distribution, standardized residuals, a and c, and q-q plot, e; and for the number of Black Grouper observed at a station using a gamma distribution, standardized residuals, b and d, and q-q plot, f.

e. f.

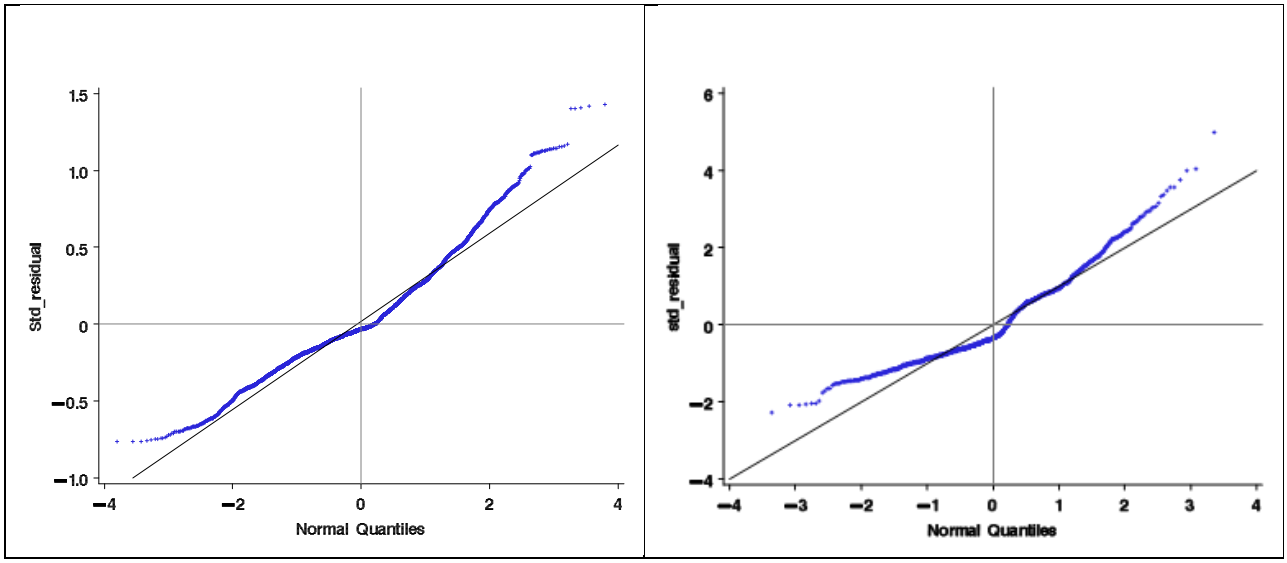

Figure 1 continued. Diagnostic plots for the probability fit using a binomial distribution, standardized residuals (a), q-q plot (c), and standardized residual distribution €, and for the number of Black Grouper observed at a station, , standardized residuals (b), q-q plot (d), and standardized residual distribution (f).

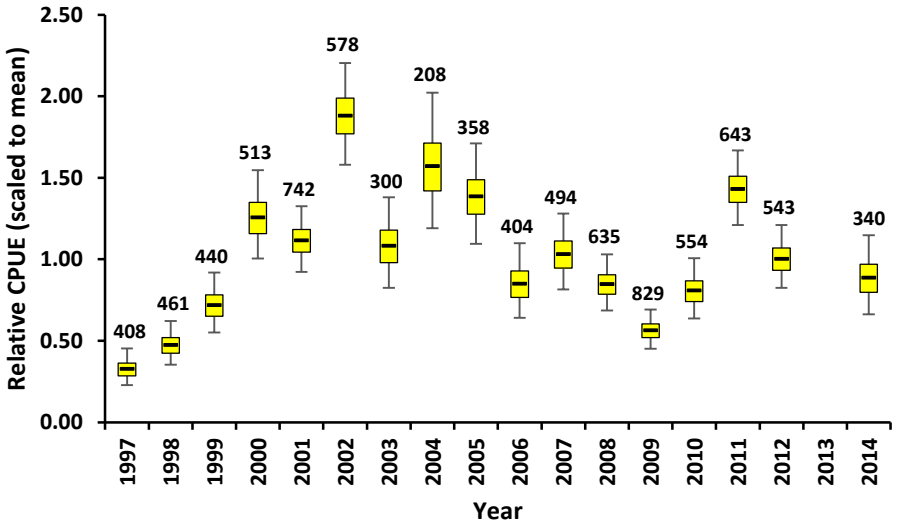

Figure 2. A box-whisker plot of the Reef Fish Visual Census index by year. . The horizontal line is the median estimate; the box is the inter-quartile range, and the vertical line is the 95% confidence interval. The number of stations sampled each year is shown above the confidence interval.

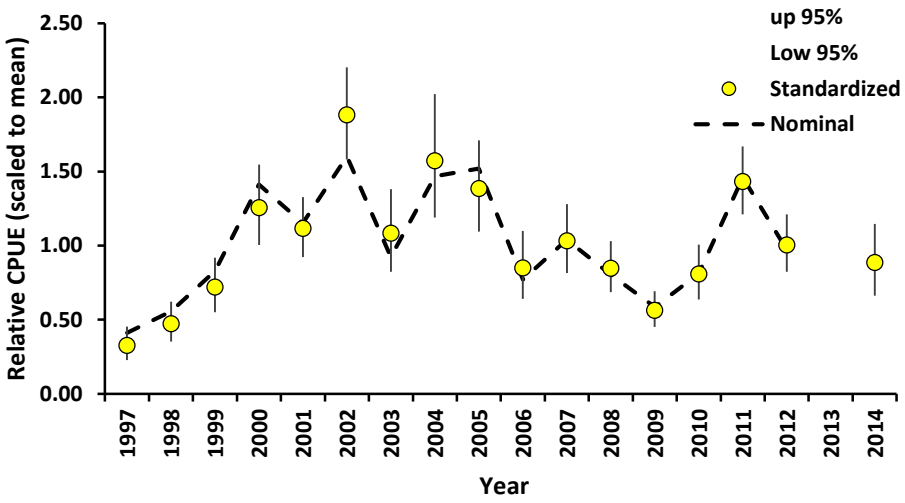

Figure 3. Comparison of standardized catch rates with their confidence intervals and nominal catch rates by year

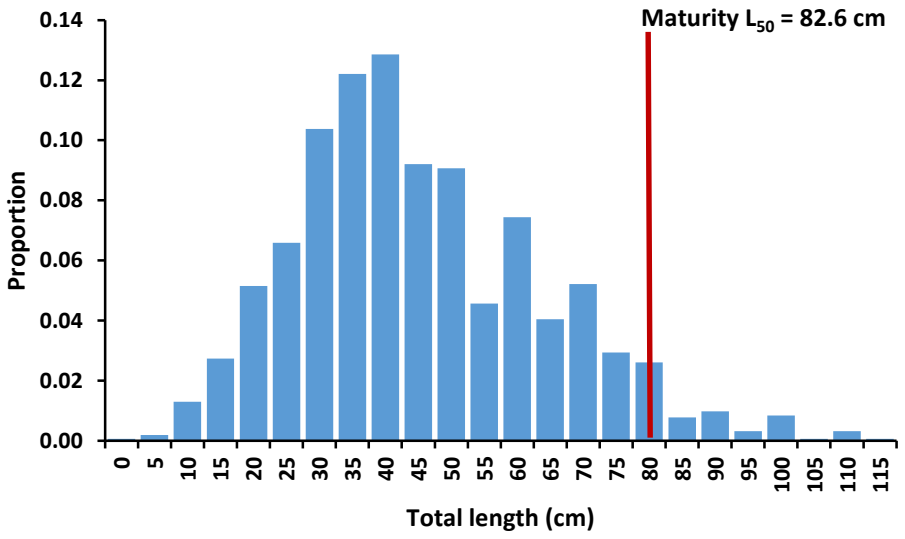

Figure 4. The distribution of total lengths of Black Grouper estimated *in situ* by Reef Fish Visual Survey divers along the Florida reef track.