Standardized Reef Fish Visual Census index for Gray Snapper, *Lutjanus griseus*, for the Florida reef track from Biscayne Bay through the Florida Keys for 1997-2016

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Standardized Reef Fish Visual Census index for Gray Snapper, *Lutjanus griseus*, for the Florida reef track from Biscayne Bay through the Florida Keys for 1997-2016.

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Abstract

Reef Fish Visual Census' observation rates for Gray Snapper, *Lutjanus griseus*, expressed as the average number of Gray Snapper observed per station, were standardized using a delta or hurdle procedure. Point count data for the Gulf of Mexico from 1997 through 2016 were extracted for the Florida Keys and Dry Tortugas omitting stations north of the Miami-Dade/Monroe County line. The extracted stations were additionally filtered to remove those stations with visibility less than 7.5 m, stations from experimental winter surveys, and stations in sand, seagrass, mud, or artificial habitats because these habitats were not part of the RVC domain. The final data set included 11,490 stations. The average number of Gray Snapper was calculated per station and potential explanatory variables included year (1997 to 2016), season (Apr-Jun, Jul-Sep, Oct-Dec), sub-regions of the reef track (Upper Keys, Middle Keys, Lower Keys, Tortugas), 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 (2.5m categories with 25 m +), and underwater visibility (2.5m categories with 25 m +). The submodel for the proportion of stations that observed Gray Snapper reduced the mean deviance by 14.8% and the submodel for the mean number of Gray Snapper observed at positive stations reduced the deviance by 18.8%. The average number of Gray Snapper observed per station in 2014 and 2016 were among the highest in the time series.

Introduction

Personnel from the National Marine Fisheries Service began the Reef Fish Visual Census (RVC) in 1979 counting fish along the Florida reef track from Biscayne Bay to the Florida Keys (Bohnsack and Bannerot 1986; Bohnsack *et al.* 1999; and Ault *et al.* 2001). They employed a two-stage stratified random survey design (Cochran 1977) with sampling frames by habitat that were created by dividing the Florida reef track into 200 m x 200 m blocks and listing the habitats in each block. The block size later was reduced to 100 m x 100 m in 2014 to improve the spatial resolution. The change in the block size does not affect the index because the index is a measure of the average number of Gray Snapper observed by the divers at a station. Annually (biennially after 2012), blocks were randomly selected by habitat and SCUBA divers (usually two) were deployed at each of two randomly located stations within the blocks. The divers identified and counted 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). Since 1997, the divers record whether the station being sampled 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 (1998) recommended using fishery-independent indices whenever possible because fishery independent surveys are statistically designed and unaffected by regulatory changes such as changes in size limits or trip or bag limits. Most of the fishery independent sampling programs used in SEDAR assessments occur in deeper waters than

where Gray Snapper occur. The Reef Fish Visual Census (RVC) is a fishery-independent source that operates in a prime habitat for Gray Snapper.

Methods

With the establishment of Sanctuary Protected Areas by the Florida Keys National Marine Sanctuary in 1997, the RVC personnel recommended only using data from 1997 and later for consistency with their revised and improved sampling design; therefore, I extracted the RVC station point count data for the Florida Keys and Dry Tortugas for the 1997 through 2016; there was no sampling in 2013 nor 2015 due to the biennial sampling schedule. For Gray Snapper, the boundary between the Gulf of Mexico and South Atlantic waters is the line between Miami- Dade County and Monroe County. For the reef track, this meant extending that county line east from the middle of the channel between Swan Key and Palo Alto Key (just north of Key Largo, 25.342941 N, 80.250626 W) and removing stations north of this line. Additional filtering of the RVC data included deleting the experimental winter surveys that were conducted in 2004/2005, omitting stations with underwater visibility less than 7.5 m (the diver's observation radius), and removing stations that were conducted in sand, seagrass, mud, or artificial habitats because these habitats were not part of the RVC domain. 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, depth, and habitat; and region which was based on the subregion of the Florida Keys) but these fields could be constructed from other reported information. The basic observation is the average number of fish observed by the divers at a station. The final dataset consisted of 11,490 station samples (Fig. 1).

Similar to the approach that Ingram and Harper (2009) used for Black Grouper, the index was standardized with the delta or hurdle approach which split the process into two generalized linear submodels (Lo *et al.* 1992): a submodel to estimate the proportion of stations where Gray Snapper were observed with a binomial distribution that used a logit link and a submodel to estimate the mean number of Gray Snapper caught at a positive station with either a gamma, Poisson, or log-normal distribution for the number of Gray Snapper observed at positive stations. 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 Gray Snapper (***$\hat{Y}$***) by year after they each have been back-calculated from their linear forms (for the logit link, the transform was $prop = \frac{e^{f(x1+x2+..)}}{1+e^{f(x1+x2+..)}}$ and for the Poisson and gamma distributions (log link) and the log-normal distribution (identity link), 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 2016), season (Apr-Jun, Jul-Sep, Oct-Dec), sub-regions of the reef track (Upper Keys, Middle Keys, Lower Keys, Dry Tortugas), 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 (2.5m categories with 25 m +), and underwater visibility (2.5m categories with 25 m +). All 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 final versions of the respective submodels. To be included in the final submodel, variables 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 index values, 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 log scale and uncertainty was added by multiplying the annual least-squares mean estimate's standard error by a random normal deviate (μ=0, σ=1). As described above, these values were transformed back from their linear scales and multiplied together.

Results and Discussion

The submodel estimating the probability that a diver observed at least one Gray Snapper at a station reduced the deviance by 14.8% and the variables in the final submodel listed in decreasing order of importance included habitat, zone or reef type, depth category, and year (Table 1). Diagnostic plots for the probability of seeing a Gray Snapper at a station submodel are shown in Fig. 2. The submodel with the Poisson distribution for estimating the number of Gray Snapper observed at successful stations slightly edged out the gamma distribution by reducing the deviance by 18.8% while the submodel with the gamma distribution reduced the deviance by 16.4%; the submodel with the log-normal distribution was further back reducing the deviance just 7.4%. Seven variables were selected for the final submodel, listed in decreasing order of importance, included habitat, visibility category, reef type, subregion, depth category, year, and, protected area (Table 2). A residual plot of the number of Gray Snapper observed at a positive station submodel is also shown in Fig.2. The models had a difficult time fitting stations with average numbers observed exceeding 150 fish on a single dive 30-min dive (20 observations). The maximum number of Gray Snapper was a mean of 1605 Gray Snapper observed at a single station and another station reported an average of 605 Gray Snapper on a single dive.

The Reef Fish Visual Census index for Gray Snapper varied without trend from 1997 until 2011 and then increased to a new level with low value in 2012 (Table 3, Fig. 3); the 2016 value (5.49 fish per station) was the third highest in the time series. The coefficients of variation were reasonable ranging from 0.102 to 0.154. The nominal index had a similar shape as the standardized RVC index with some exceptions (Fig. 4).

The median size of the Gray Snapper in the Florida Keys (*n* = 15,233) as estimated by the divers *in situ* was 268 mm TL and the interquartile range was 215 to 326 mm TL (Fig. 5). Fitzhugh *et al.* (2017) found that the length at which 50% of the Gray Snapper are mature was 268 mm TL (253 mm FL) and the 10th percentile length was 152 mm TL (144 mm FL) and the 90th percentile was 384 mm TL (362 mm FL). Therefore, 47% of the observed Gray Snapper were at least the size of 50% maturity.

Literature cited

Ault, J.S., S.G. Smith, G.A. Meester, J. Luo, J. and A. Bohnsack. 2001. Site Characterization for Biscayne National Park: assessment of fisheries resources and habitats. NOAA Technical Memorandum NMFS-SEFSC-468. 165 pp.

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report NMFS 41. 15 pp.

Bohnsack, J.A., D.B. McClellan, D.E. Harper, G.S. Davenport, G.J. Konoval, A-M. Eklund, J.P. Contillo, S.K. Bolden, P.C. Fishel, G.S.Sandorf, J.C. Javech, M. W. White, M.H. Oickett, M.W. Hulsbeck, J.L. Tobias, J.S.

Ault, G. A. Meester, S.G. Smith, and Jiangang Luo. 1999. Baseline data for evaluating reef fish populations in the Florida Keys, 1979-1998. NOAA Technical Memorandum NMFS-SEFSC-427. 63 pp.

Cochran, W.G. 1977. Sampling techniques. John Wiley and Sons, New York. 428 pp.

Fitzhugh, G.R., V.C. Beech, H.M. Lyon, and P. Colson. 2017. Reproductive parameters for the Gulf of Mexico gray snapper, *Lutjanus griseus,* 1991-2015. SEDAR51-DW-06. SEDAR, North Charleston, SC. 9 pp.

Ingram, Jr., G.W. and D.E. Harper. 2009. Patterns of annual abundance of black grouper and red grouper in the Florida Keys and Dry Tortugas based on reef fish visual census conducted by NOAA NMFS. SEDAR 19-DW-11. SEDAR. North Charleston, SC. 85 pp.

Lo, N.C.N, L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on Delta-Lognormal models. Canadian Journal of Fishery and Aquatic Science 49:2515-2526.

National Research Council. 1998. Improving fish stock assessments. National Academy Press. Washington, D.C. 177 pp.

Table 1. Stepwise selection of variables for their inclusion in estimating the probability of observing a Gray Snapper at a Reef Fish Visual Census station (shaded lines) if the Gulf of Mexico waters of the Florida Keys including the Dry Tortugas 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
NULL	11489	13561.0	1.180	.	.	.	.	Conv	
Habitat	11481	12092.9	1.053	8	1468.08	0	10.76	Conv	10.8
Reef type	11482	13070.5	1.138	7	490.45	0	3.56	Conv	
Depth	11479	13311.1	1.160	10	249.88	0	1.76	Conv	
Year	11472	13373.4	1.166	17	187.58	0	1.24	Conv	
Protected	11488	13446.1	1.170	1	114.85	0	0.84	Conv	
Subregion	11484	13444.2	1.171	5	116.73	0	0.82	Conv	
Visibility	11482	13530.0	1.178	7	30.93	6.4E-05	0.17	Conv	
Season	11487	13552.1	1.180	2	8.85	0.0120	0.05	Conv	
Habitat Reef_type	11474	11777.0	1.026	7	315.89	0	2.28	Conv	13.0
Habitat Subregion	11476	11911.6	1.038	5	181.33	0	1.30	Conv	
Habitat Depth	11471	11938.6	1.041	10	154.27	0	1.06	Conv	
Habitat Year	11464	11949.6	1.042	17	143.25	0	0.93	Conv	
Habitat Season	11479	12058.5	1.050	2	34.39	0	0.24	Conv	
Habitat Visibility	11474	12084.3	1.053	7	8.63	0.2806	0.01	Conv	
Habitat Protected	11480	12092.5	1.053	1	0.39	0.5340	-0.01	Conv	
Habitat Reef_type Depth	11464	11614.2	1.013	10	162.85	0	1.13	Conv	14.2
Habitat Reef_type Year	11457	11664.3	1.018	17	112.65	0	0.70	Conv	
Habitat Reef_type Subregion	11469	11733.4	1.023	5	43.60	0	0.28	Conv	
Habitat Reef_type Season	11472	11757.9	1.025	2	19.13	7.0E-05	0.13	Conv	
Habitat Reef_type Protected	11473	11772.9	1.026	1	4.12	0.0423	0.02	Conv	
Habitat Reef_type Visibility	11467	11771.9	1.027	7	5.05	0.6534	-0.02	Conv	

Table 1 continued. Stepwise selection of variables for their inclusion in estimating the probability of observing a Gray Snapper at a Reef Fish Visual Census station (shaded lines) if the Gulf of Mexico waters of the Florida Keys including the Dry Tortugas 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
Habitat Reef_type Depth Year	11447	11507.0	1.005	17	107.19	0	0.67	Conv	14.8
Habitat Reef_type Depth Subregion	11459	11553.8	1.008	5	60.37	0	0.41	Conv	
Habitat Reef_type Depth Season	11462	11597.2	1.012	2	16.95	0.0002	0.11	Conv	
Habitat Reef_type Depth Protected	11463	11610.7	1.013	1	3.46	0.0628	0.02	Conv	
Habitat Reef_type Depth Visibility	11457	11606.2	1.013	7	7.99	0.3336	0.01	Conv	

Table 2. Stepwise selection of variables to include in estimating the number of Gray Snapper observed at positive Reef Fish Visual Census stations in the Florida Keys (shaded lines) with a GLM (Poisson distribution and log link). The fields include the variable, degrees of freedom, deviance, mean deviance, Chi-square degrees of freedom, Chi-square value, probability of the null hypothesis, percent reduction in deviance, whether the model converged, and the cumulative percent reduction in deviance.

Explanatory variable	Degrees of freedom	Deviance	Mean deviance	Chi-square degrees of freedom	Chi-square	Probability of null hypothesis	Percent reduction in deviance	Converged	Cumulative percent reduction in mean deviance
NULL	3182	81790.2	25.704	.	.	.	.	Conv	
Habitat	3174	78227.5	24.646	8	3562.63	0	4.12	Conv	4.1
Reef type	3175	78817.3	24.824	7	2972.90	0	3.42	Conv	
Depth	3172	78864.8	24.863	10	2925.40	0	3.27	Conv	
Visibility	3175	79022.8	24.889	7	2767.41	0	3.17	Conv	
Year	3165	78931.8	24.939	17	2858.32	0	2.98	Conv	
Subregion	3177	79568.4	25.045	5	2221.77	0	2.56	Conv	
Protected	3181	81071.8	25.486	1	718.32	0	0.85	Conv	
Season	3180	81670.4	25.683	2	119.73	0	0.08	Conv	
Habitat Visibility	3167	74780.3	23.612	7	3447.18	0	4.02	Conv	8.1
Habitat Year	3157	75097.0	23.787	17	3130.54	0	3.34	Conv	
Habitat Reef_type	3167	75656.8	23.889	7	2570.68	0	2.95	Conv	
Habitat Subregion	3169	75779.4	23.913	5	2448.13	0	2.85	Conv	
Habitat Depth	3164	75774.8	23.949	10	2452.77	0	2.71	Conv	
Habitat Protected	3173	77568.7	24.446	1	658.80	0	0.78	Conv	
Habitat Season	3172	78016.4	24.595	2	211.11	0	0.20	Conv	
Habitat Visibility Reef type	3160	71712.5	22.694	7	3067.84	0	3.57	Conv	11.7
Habitat Visibility Depth	3157	71884.6	22.770	10	2895.74	0	3.28	Conv	
Habitat Visibility Subregion	3162	72798.3	23.023	5	1982.09	0	2.29	Conv	
Habitat Visibility Year	3150	72949.3	23.159	17	1831.03	0	1.77	Conv	
Habitat Visibility Protected	3166	74041.9	23.387	1	738.49	0	0.88	Conv	
Habitat Visibility Season	3165	74657.1	23.588	2	123.20	0	0.09	Conv	

Table 2 continued. Stepwise selection of variables to include in estimating the number of Gray Snapper observed at positive Reef Fish Visual Census stations (shaded lines) with a GLM (Poisson 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
Habitat Visibility Reef type Subregion	3155	69174.0	21.925	5	2538.51	0	2.99	Conv	14.7
Habitat Visibility Reef type Depth	3150	69769.4	22.149	10	1943.15	0	2.12	Conv	
Habitat Visibility Reef type Year	3143	70331.4	22.377	17	1381.16	0	1.23	Conv	
Habitat Visibility Reef type Protected	3159	70856.3	22.430	1	856.24	0	1.03	Conv	
Habitat Visibility Reef type Season	3158	71446.1	22.624	2	266.44	0	0.27	Conv	
Habitat Visibility Reef type Subregion Depth	3145	67712.7	21.530	10	1461.29	0	1.54	Conv	16.2
Habitat Visibility Reef type Subregion Year	3138	67783.0	21.601	17	1390.98	0	1.26	Conv	
Habitat Visibility Reef type Subregion Protected	3154	68353.8	21.672	1	820.19	0	0.99	Conv	
Habitat Visibility Reef type Subregion Season	3153	68947.3	21.867	2	226.67	0	0.23	Conv	
Habitat Visibility Reef type Subregion Depth Year	3128	66051.0	21.116	17	1661.72	0	1.61	Conv	17.8
Habitat Visibility Reef type Subregion Depth Protected	3144	66850.1	21.263	1	862.66	0	1.04	Conv	
Habitat Visibility Reef type Subregion Depth Season	3143	67506.9	21.478	2	205.86	0	0.20	Conv	
Habitat Visibility Reef type Subregion Depth Year Protected	3127	65295.9	20.881	1	755.13	0	0.91	Conv	18.8
Habitat Visibility Reef type Subregion Depth Year Season	3126	65639.2	20.998	2	411.78	0	0.46	Conv	

Table3. The Reef Fish Visual Census index, its coefficient of variation, the number of stations sampled, the number of stations in the Florida Keys where Gray Snapper 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 Gray Snapper	Index scaled to mean	Nominal index	Nominal index scaled to mean
1997	1.96	0.141	341	116	0.65	1.90	0.62
1998	3.73	0.126	394	168	1.24	4.38	1.43
1999	3.63	0.111	730	221	1.21	2.17	0.71
2000	4.02	0.113	842	229	1.34	2.46	0.80
2001	4.84	0.124	668	178	1.61	3.44	1.12
2002	4.14	0.122	429	117	1.38	2.86	0.93
2003	2.64	0.154	231	60	0.88	2.13	0.70
2004	2.01	0.130	734	170	0.67	3.10	1.01
2005	3.35	0.144	309	73	1.11	2.26	0.74
2006	2.19	0.126	746	159	0.73	1.69	0.55
2007	2.74	0.146	414	81	0.91	1.99	0.65
2008	3.00	0.116	1126	276	1.00	3.87	1.26
2009	3.90	0.115	714	159	1.30	2.61	0.85
2010	3.23	0.102	1116	330	1.08	2.41	0.79
2011	6.26	0.123	552	112	2.09	3.04	0.99
2012	3.57	0.103	1257	385	1.19	3.38	1.10
2013							
2014	7.83	0.112	420	168	2.61	7.52	2.45
2015							
2016	5.49	0.107	467	181	1.83	4.53	1.48

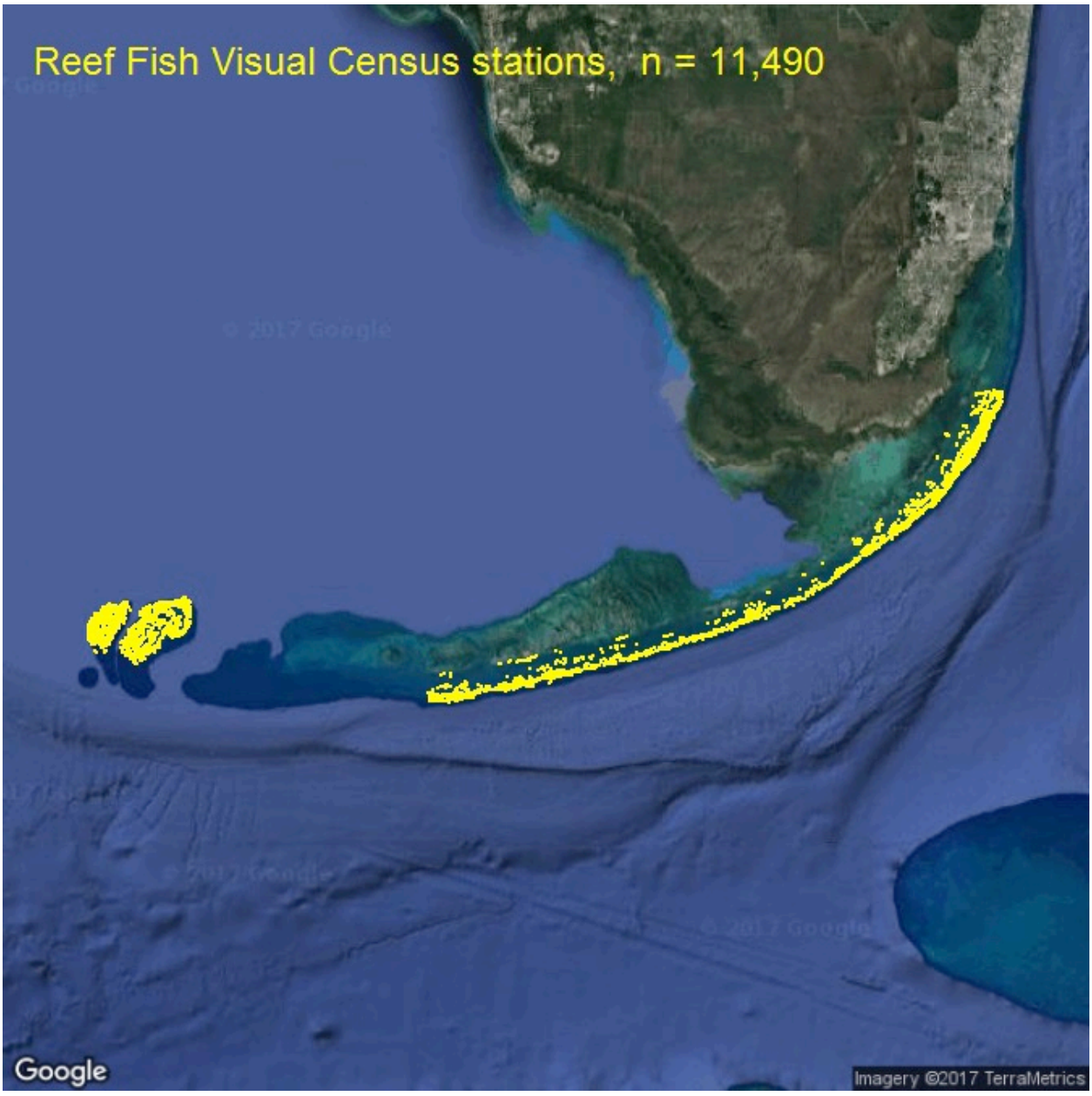

Figure 1. Reef Fish Visual Census station locations sampled in the Gulf of Mexico waters of the Florida Keys including the Dry Tortugas from 1997 to 2016.

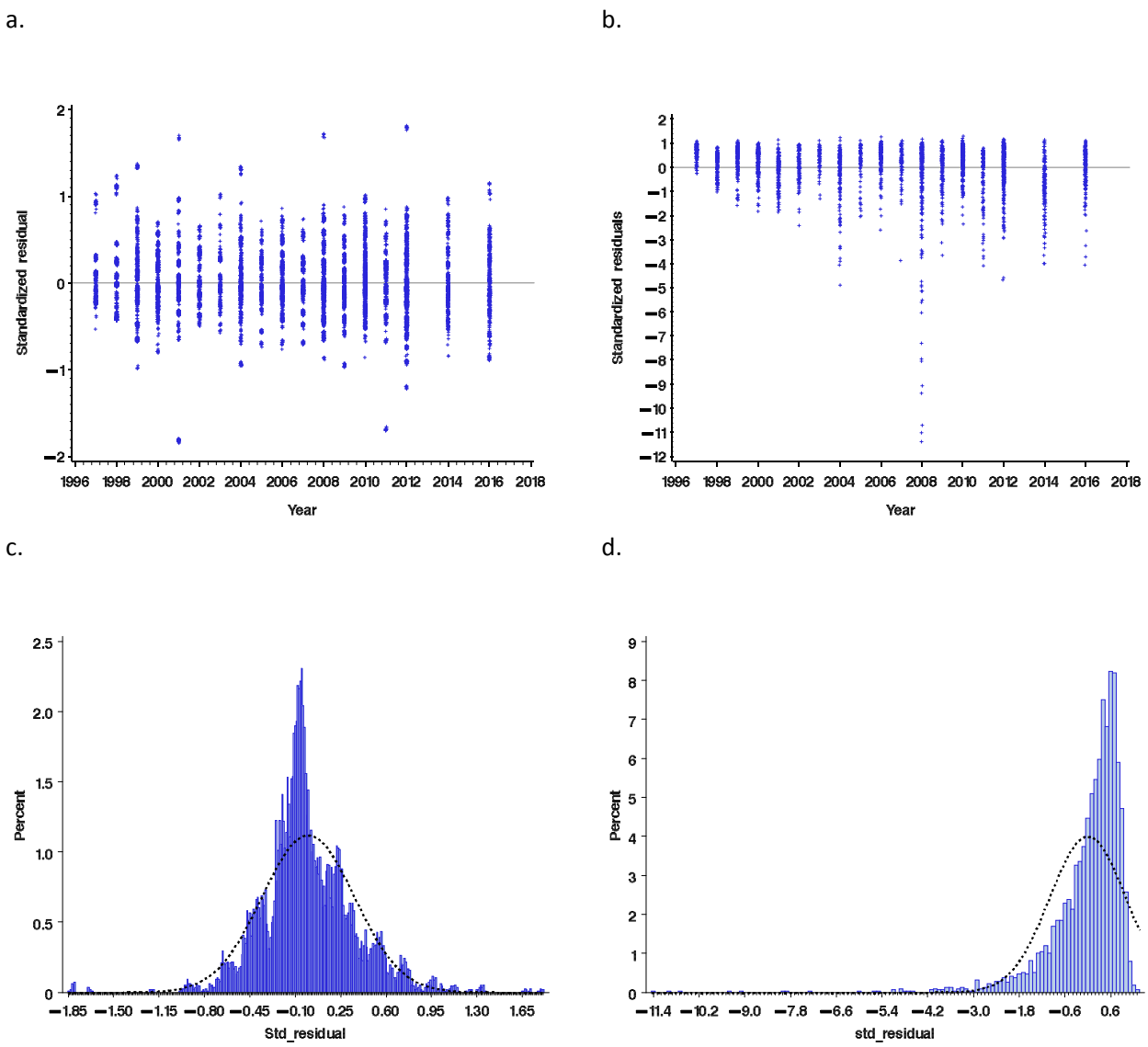

Figure 2. Diagnostic plots for the probability fit using a binomial distribution, standardized residuals, a and c, and q-q plot, e; and for the number of Gray Snapper observed at a station using a Poisson distribution, standardized residuals, b and d, and q-q plot, f.

e. f.

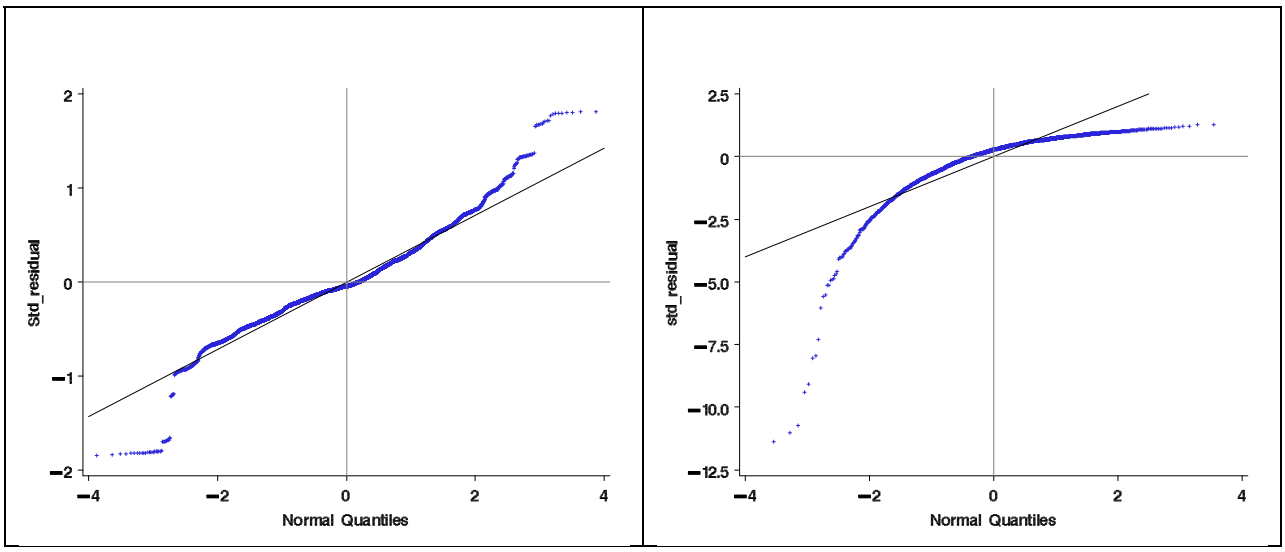

Figure 2 continued. Diagnostic plots for the probability fit using a binomial distribution, standardized residuals (a), q-q plot (c), and standardized residual distribution (e), and for the number of Gray Snapper observed at a station using a Poisson distribution, standardized residuals (b), q-q plot (d), and standardized residual distribution (f).

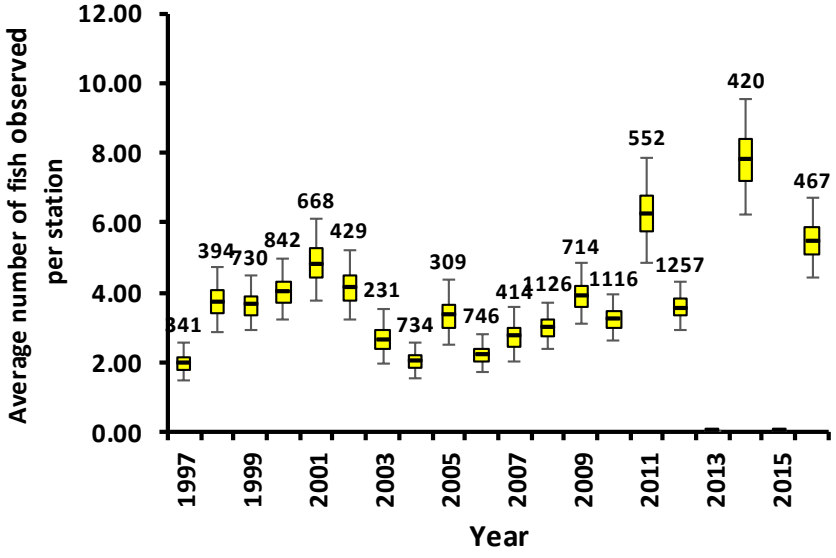

Figure 3. A box-whisker plot of the Reef Fish Visual Census Gray Snapper index by year. The horizontal line is the median estimate; the box is the inter-quartile range, and the vertical line is the 95% confidence interval. The number of stations sampled each year is shown above the confidence interval.

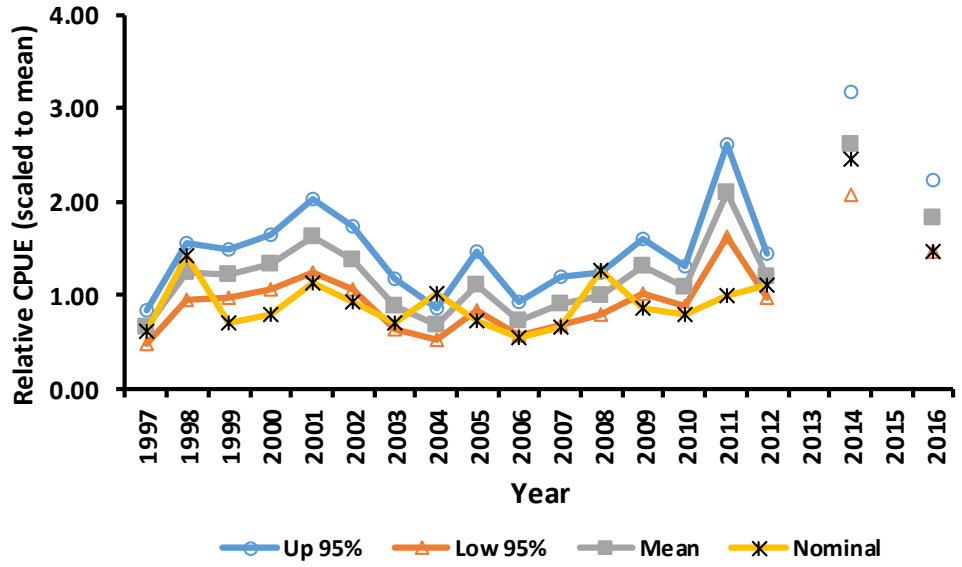

Figure 4. Comparison of standardized mean Gray Snapper catch rates with their confidence intervals and nominal catch rates scaled to their means by year.

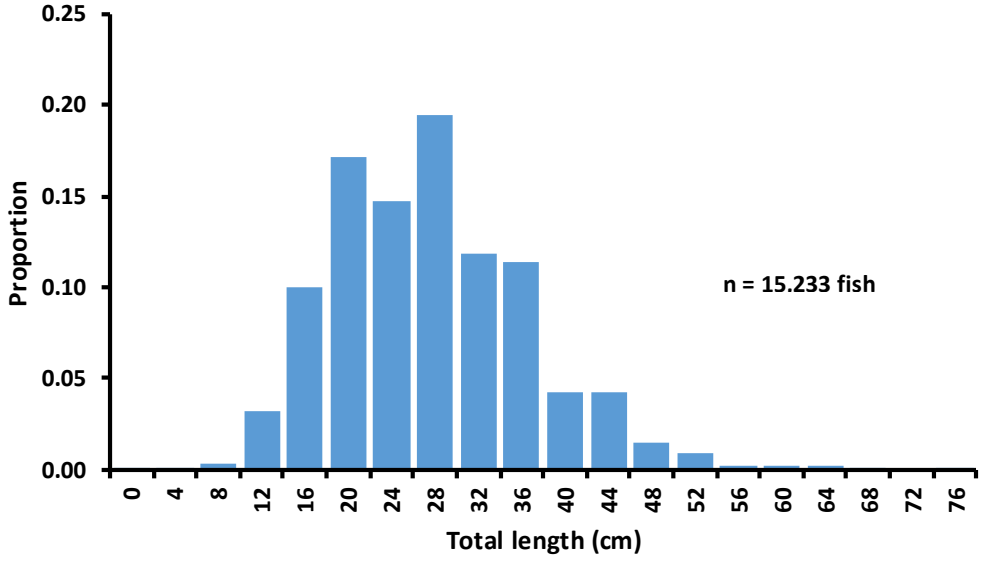

Figure 5. The distribution of total lengths of Gray Snapper estimated *in situ* by Reef Fish Visual Survey divers along the Florida reef track including the Dry Tortugas from 1997 to 2016.