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Red Grouper Abundance Indices from NMFS Bottom Longline Surveys in the Northern Gulf of Mexico

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Abstract: *The Southeast Fisheries Science Center Mississippi Laboratories (MSLABS) has conducted standardized bottom longline surveys in the Gulf of Mexico, Caribbean, and Western North Atlantic Ocean since 1995. Additionally in 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted, where high levels of survey effort were maintained from April through October. Data from the MSLABS Bottom Longline Survey and the CSSP Survey were used to produce an abundance index for red grouper.*

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories (MSLABS) has conducted standardized bottom longline surveys in the Gulf of Mexico (GOM), Caribbean, and Western North Atlantic Ocean (Atlantic) since 1995. The objective of these surveys is to provide fisheries independent data for stock assessment purposes for as many species as possible. These surveys are conducted annually in U.S. waters of the GOM and/or the Atlantic, and provide an important source of fisheries independent information on sharks, snappers and groupers. The evolution of these surveys has been the subject of many documents [e.g., Ingram *et al*. 2005 (LCS05/06-DW-27)] and was not described again in this document.

In 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted, where high levels of survey effort were maintained from April through October (for a full review of the CSSP see Campbell *et al.* 2012). This program was conducted using the same gear as the annual bottom longline survey and a similar survey design. The only difference was the CSSP sampled out to 400 m, whereas, the annual survey samples to a depth of 366 m. The purpose of this document is to provide an abundance index for red grouper (*Epinephelus morio*).

Methodology

Survey Design

Details concerning methodologies and evolution of the NMFS BLL have been covered in previous documents (most recently LCS05/06-DW-27) and will not be repeated in this document. Basic sample design was a proportional allocation of stations based on continental shelf width within statistical zones and stratified by depth (50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m). The survey used 15/0 circle hooks, but in the past J-hooks had been used. Henwood *et al.* (2005) examined the difference in catch rates between the two hooks types and only found significant difference at shallow stations (< 30 fathoms).

Data

Data for the annual bottom longline survey was obtained from the SEFSC MSLABS Shark Unit and the CSSP data was obtained from SEFSC MSLABS Information Technology Unit. Data from the CSSP was used to fill in gaps in the annual bottom longline survey due to vessel breakdowns and weather delays in 2011. As to not over represent any one area, data from the August survey was used for the Eastern GOM, while data from September was used for the Western and Central GOM. These time frames historically match up with when the annual bottom longline survey sampled those areas. For this document, the combined dataset will be hereafter referred to as NMFS BLL. The total number of stations sampled in the GOM was 3,083 (Table 1). Age data were obtained from the SEFSC Panama City Laboratory.

Data Exclusions

We used the time series of data between 2001 and 2013 to develop red grouper abundance indices (Table 1). Data from 1995 – 2000 was not used due to the use of J-type hooks, attributing to very few red grouper (53) being captured. With the change to circle-hooks, red grouper catch increased by an order of magnitude (LCS05/06-DW-27). Survey year 2002 was dropped from analysis because of the limited spatial coverage in the eastern GOM. Data was limited spatially to an area east of 87°W, since no red grouper had been captured past this point. Depth was also used to limit the data, with no stations deeper than 118 m being used, since there were no records of red grouper being caught any deeper. In 2005, additional sampling was done in October and November (43 stations) since most of the survey was canceled due to Hurricane Katrina. However, there was little temporal overlap in other years (17 stations in 2004), so all stations done outside of August and September were removed. After limiting the data, 837 stations were used in the analysis.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for red grouper (Pennington, 1983; Bradu & Mundlak, 1970). The main advantage of using this method is allowance for the probability of zero catch (Ortiz *et al.* 2000). The index computed by this method is a mathematical combination of yearly abundance estimates from two distinct generalized linear models: a binomial (logistic) model which describes proportion of positive abundance values (i.e. presence/absence) and a lognormal model which describes variability in only the nonzero abundance data (*cf.* Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) was estimated as:

(1) $I_y = c_y p_y$,

where c_y is the estimate of mean CPUE for positive catches only for year y, and p_y is the estimate of mean probability of occurrence during year y. Both c_y and p_y were estimated using generalized linear models. Data used to estimate abundance for positive catches (c) and probability of occurrence (p) were assumed to have a lognormal distribution and a binomial distribution, respectively, and modeled using the following equations:

(2) $$\ln(c) = X\beta + \varepsilon$$

and

(3) $$p = \frac{e^{X\beta+\varepsilon}}{1 + e^{X\beta+\varepsilon}},$$

respectively, where c is a vector of the positive catch data, p is a vector of the presence/absence data, X is the design matrix for main effects, β is the parameter vector for main effects, and ε is a vector of independent normally distributed errors with expectation zero and variance σ^2. Therefore, c_y and p_y were estimated as least-squares means for each year along with their corresponding standard errors, SE (c_y) and SE (p_y), respectively. From these estimates, I_y was calculated, as in equation (1), and its variance calculated using the delta method approximation

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y).$$

A covariance term is not included in the variance estimator since there is no correlation between the estimator of the proportion positive and the mean CPUE given presence. The two estimators are derived independently and have been shown to not covary for a given year (Christman, unpublished).

The submodels of the delta-lognormal model were built using a backward selection procedure based on type 3 analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using AIC, while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and QQ plots in addition to AIC. Variables that could be included in the submodels were:

Submodel Variables (GOM)

Year: 2001, 2003 – 2013
Depth: 9 – 118 meters (continuous)
Area: Northern (north of 29°N), Central (between 27°N - 29°N), Southern (south of 27°N)
Time of Day: Day, Night

Results and Discussion

Size and Age

The distribution of red grouper is presented in Figure 1, with annual abundance and distribution presented in Appendix Figure 1. There were 20 to 330 red grouper captured per year (Table 2). Of the 1,284 red grouper captured, a total of 1,188 were measured from 2001 – 2013 with an average fork length of 508 mm. Figure 2 shows the length frequency distribution of red grouper captured in the GOM. The average age of red grouper collected on bottom longlines was 6.17 years old (Figure 3).

Abundance Index

For the NMFS BLL abundance index of red grouper, the nominal CPUE and number of stations with a positive catch are presented in Figure 4. Year, area and depth were retained in the binomial submodel, while year and area were retained in the lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 3 summarizes backward selection procedure used to select the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 3,836.8 and 706.4, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 5-7, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 4 and Figure 8.

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Table 1. Summary of the total number of stations sampled per year by coverage area (top) and number of stations used in the analysis (bottom).

Year	Gulf of Mexico			Total
	East	Central	West	
1995	34	27	13	74
1996	37	25	17	79
1997	61	32	71	164
1998				
1999	57	104		161
2000	63	51	23	137
2001	130	64	83	277
2002	43	71	98	212
2003	163	54	63	280
2004	136	60	53	249
2005	80	15		95
2006	62	37	50	149
2007	71	38	47	156
2008	75	7	26	108
2009	91	43	51	185
2010	87	31	32	150
2011	178	54	65	297
2012	74	35	33	142
2013	75	47	46	168
Total	*1517*	*771*	*771*	*3083*

Year	Eastern Gulf of Mexico			Total
	Northern	Central	Southern	
1995				
1996				
1997				
1998				
1999				
2000				
2001	28	41	24	93
2002				
2003	28	41	48	117
2004	24	33	41	98
2005	3	12	25	40
2006	4	13	22	39
2007	13	9	20	42
2008	18	18	24	60
2009	14	19	30	63
2010	20	17	30	67
2011	32	48	42	122
2012	10	21	18	49
2013	16	15	16	47
Total	*231*	*289*	*340*	*837*

Table 2. Summary of the red grouper length data collected from NMFS Bottom Longline surveys conducted between 2001 and 2013.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2001	93	83	79	290	837	502	112
2002	23	20	16	373	790	543	115
2003	117	166	162	295	845	510	121
2004	98	186	170	290	786	499	105
2005	40	33	32	303	700	475	114
2006	39	43	32	370	669	520	87
2007	42	51	51	350	694	477	80
2008	60	35	31	275	800	548	132
2009	63	65	64	315	910	506	132
2010	67	86	81	320	810	506	113
2011	122	330	312	300	757	487	95
2012	49	135	111	320	749	507	90
2013	47	51	47	262	780	518	109
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
13	860	1284	1188			508	

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for red grouper index of relative abundance from 2001 to 2013.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 3850.8)*						*Lognormal Submodel Type 3 Tests (AIC 717.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	821	21.48	1.95	0.0287	0.0302	11	262	3.34	0.0003
Depth	1	821	51.49	51.49	<.0001	<.0001	1	262	0.92	0.3384
Area	2	821	39.99	19.99	<.0001	<.0001	2	262	6.41	0.0019
Time of Day	1	821	2.87	2.87	0.0904	0.0908	1	262	0.76	0.3849
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 3836.8)*						*Lognormal Submodel Type 3 Tests (AIC 715.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	822	22.01	2.00	0.0243	0.0257	11	263	3.33	0.0003
Depth	1	822	52.72	52.72	<.0001	<.0001	1	263	0.95	0.3313
Area	2	822	41.32	20.66	<.0001	<.0001	2	263	6.82	0.0013
Time of Day	Dropped						Dropped			
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 3836.8)*						*Lognormal Submodel Type 3 Tests (AIC 706.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	11	822	22.01	2.00	0.0243	0.0257	11	264	3.34	0.0002
Depth	1	822	52.72	52.72	<.0001	<.0001	Dropped			
Area	2	822	41.32	20.66	<.0001	<.0001	2	264	6.49	0.0018
Time of Day	Dropped						Dropped			

Table 4. Indices of red grouper abundance developed using the delta-lognormal model for 2001-2013. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2001	0.21505	93	0.73588	0.64446	0.29285	0.36312	1.14380
2002							
2003	0.34188	117	1.01705	0.89070	0.20235	0.59667	1.32962
2004	0.41837	98	1.65489	1.44930	0.19234	0.98994	2.12181
2005	0.25000	40	0.62097	0.54383	0.40445	0.24968	1.18452
2006	0.28205	39	0.56797	0.49741	0.39043	0.23418	1.05653
2007	0.19048	42	0.87920	0.76998	0.46373	0.31852	1.86132
2008	0.26667	60	0.60496	0.52980	0.32099	0.28321	0.99110
2009	0.34921	63	0.93405	0.81801	0.26314	0.48754	1.37249
2010	0.32836	67	1.25711	1.10094	0.26413	0.65494	1.85067
2011	0.40164	122	2.30746	2.02080	0.18133	1.41025	2.89570
2012	0.46939	49	2.14000	1.87415	0.25422	1.13615	3.09152
2013	0.34043	47	0.98270	0.86062	0.30477	0.47418	1.56199

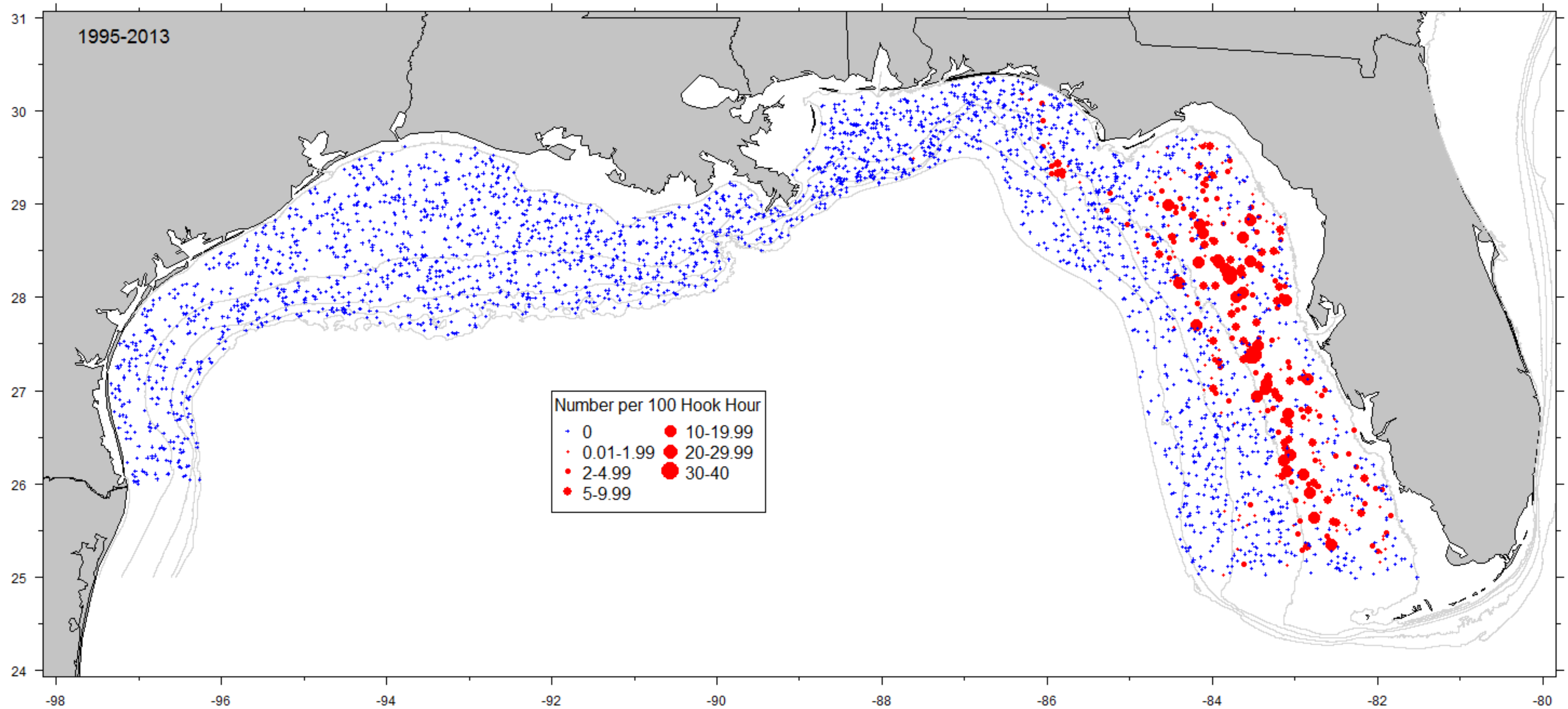


Figure 1. Stations sampled from 1995 to 2013 during the NMFS Bottom Longline Survey with the CPUE for red grouper.

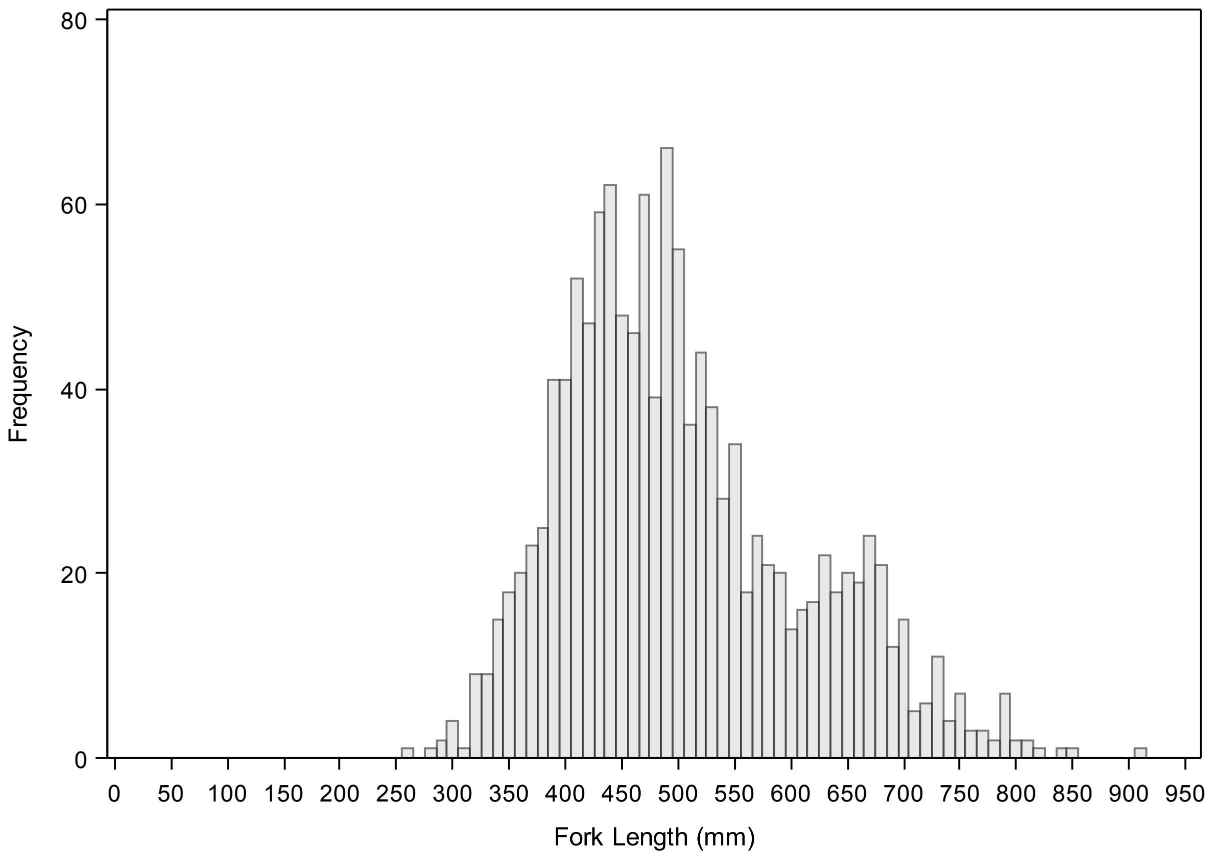
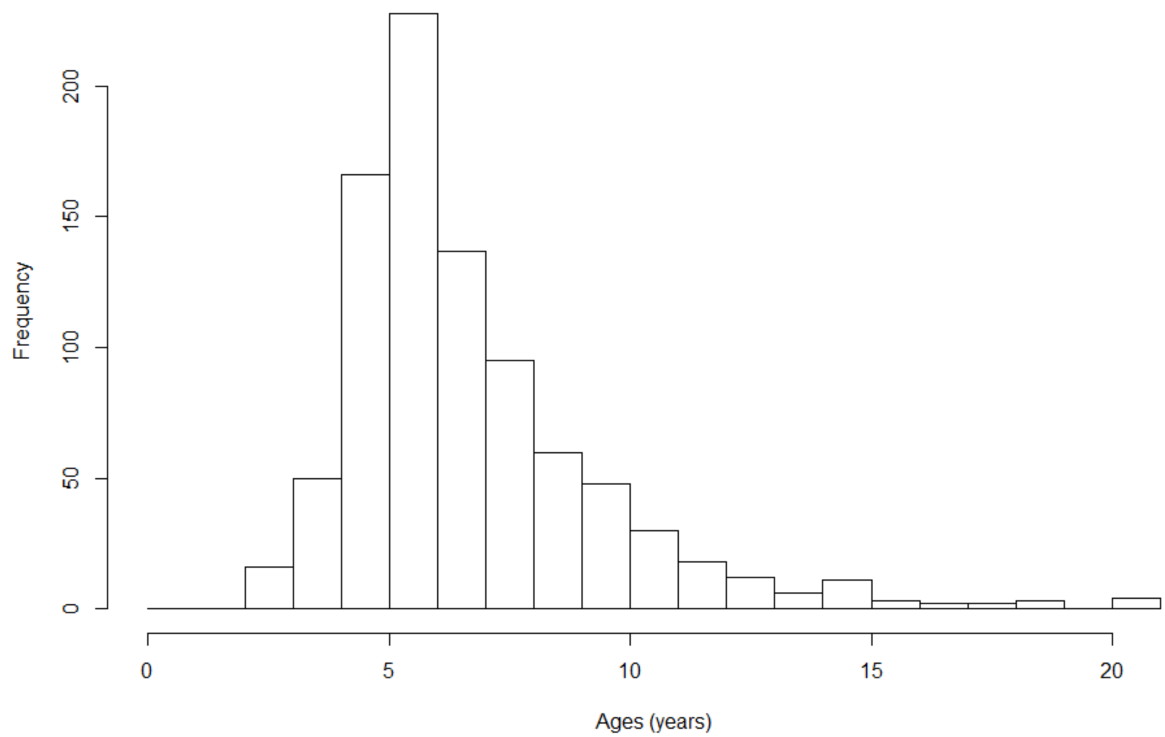


Figure 2. Length frequency histogram for red grouper captured in the Gulf of Mexico during the NMFS Bottom Longline Survey from 2001-2013.



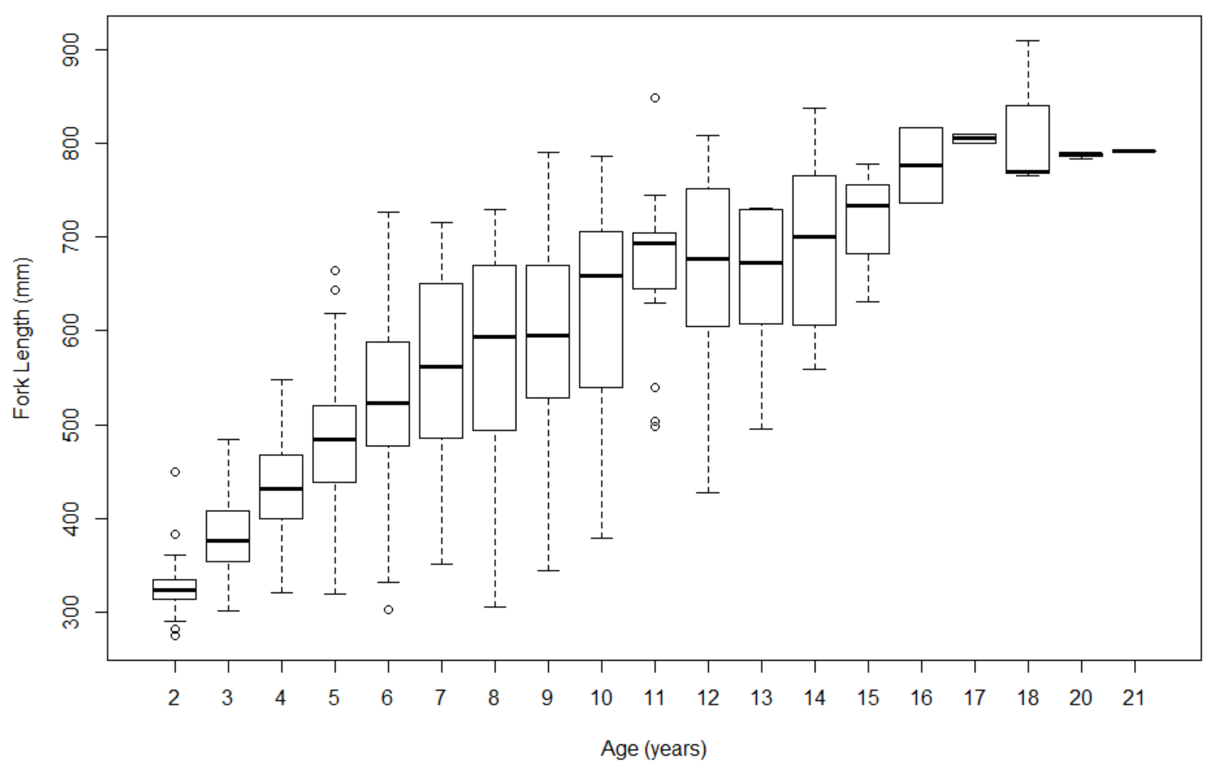


Figure 3. Age distribution of red grouper (n = 891) captured during NMFS Bottom Longline Surveys (top) and length at age information (bottom).

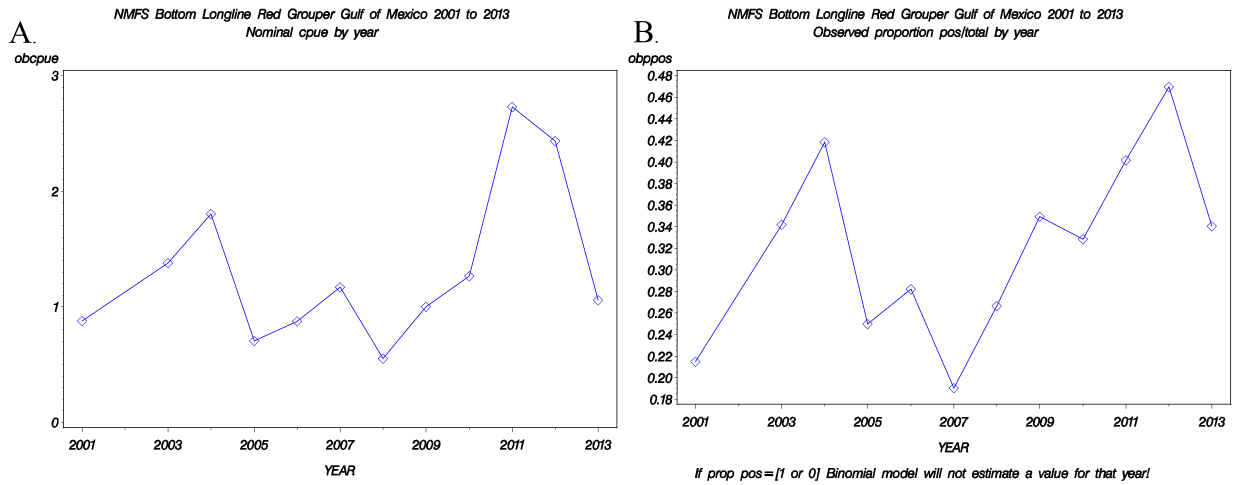


Figure 4. Annual trends for red grouper captured during NMFS Bottom Longline Surveys from 2001 to 2013 in **A.** nominal CPUE and **B.** proportion of positive stations.

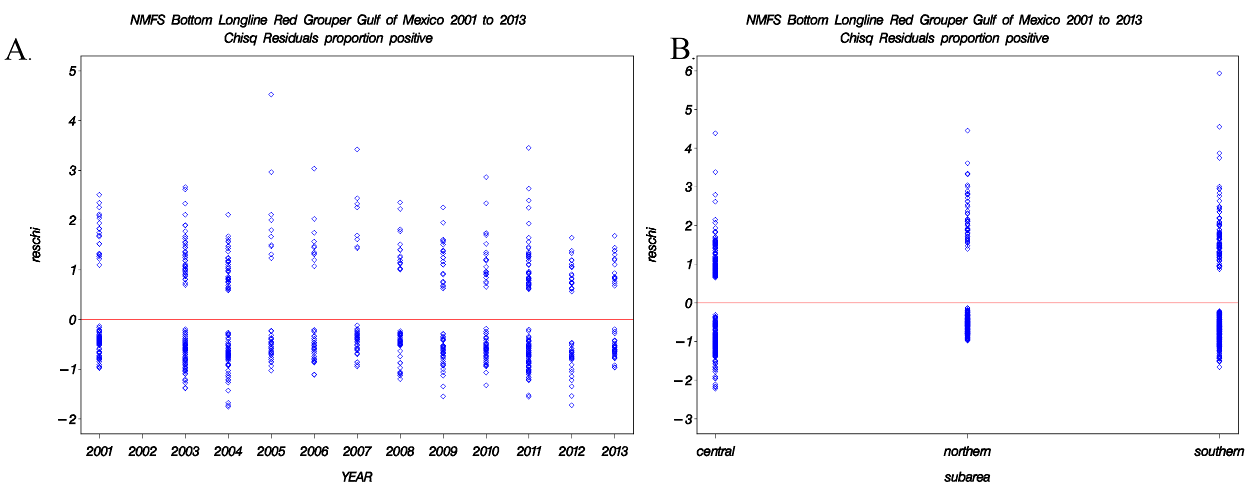


Figure 5. Diagnostic plot for binomial component of the red grouper NMFS Bottom Longline Surveys model: **A.** the Chi-Square residuals by year and **B.** the Chi-Square residuals by area.

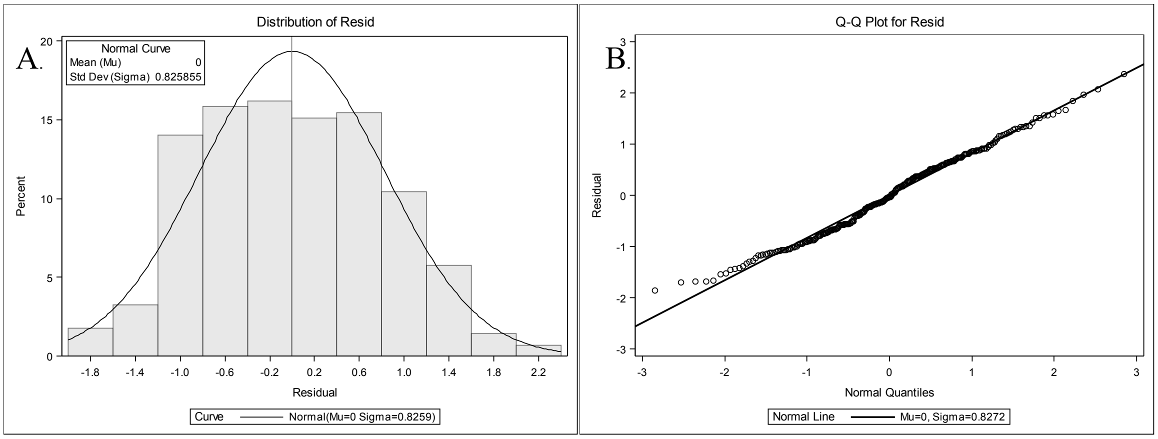


Figure 6. Diagnostic plots for lognormal component of the red grouper NMFS Bottom Longline Surveys model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

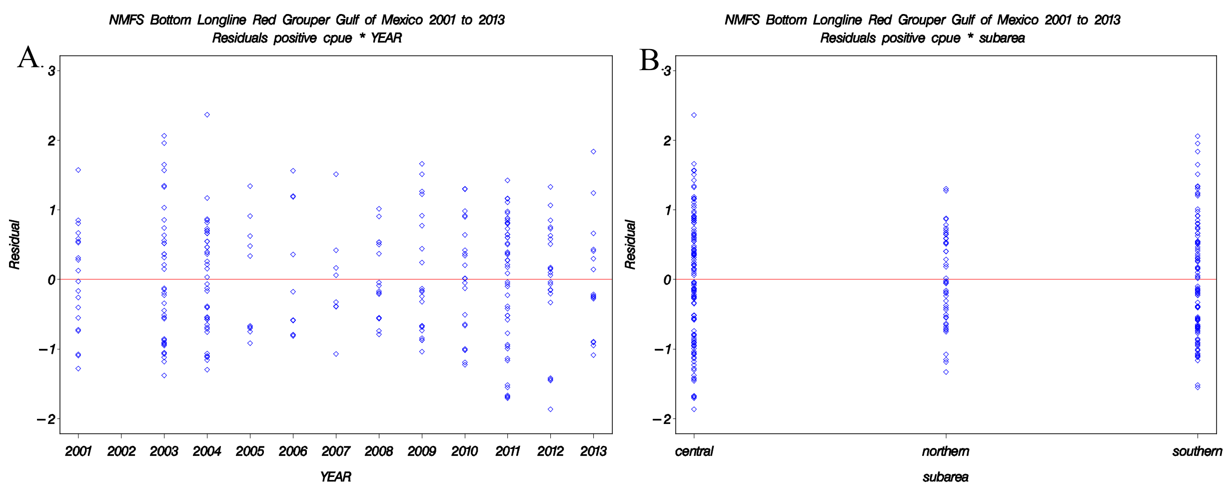


Figure 7. Diagnostic plots for lognormal component of the red grouper NMFS Bottom Longline Surveys model: **A.** the Chi-Square residuals by year and **B.** the Chi-Square residuals by area.

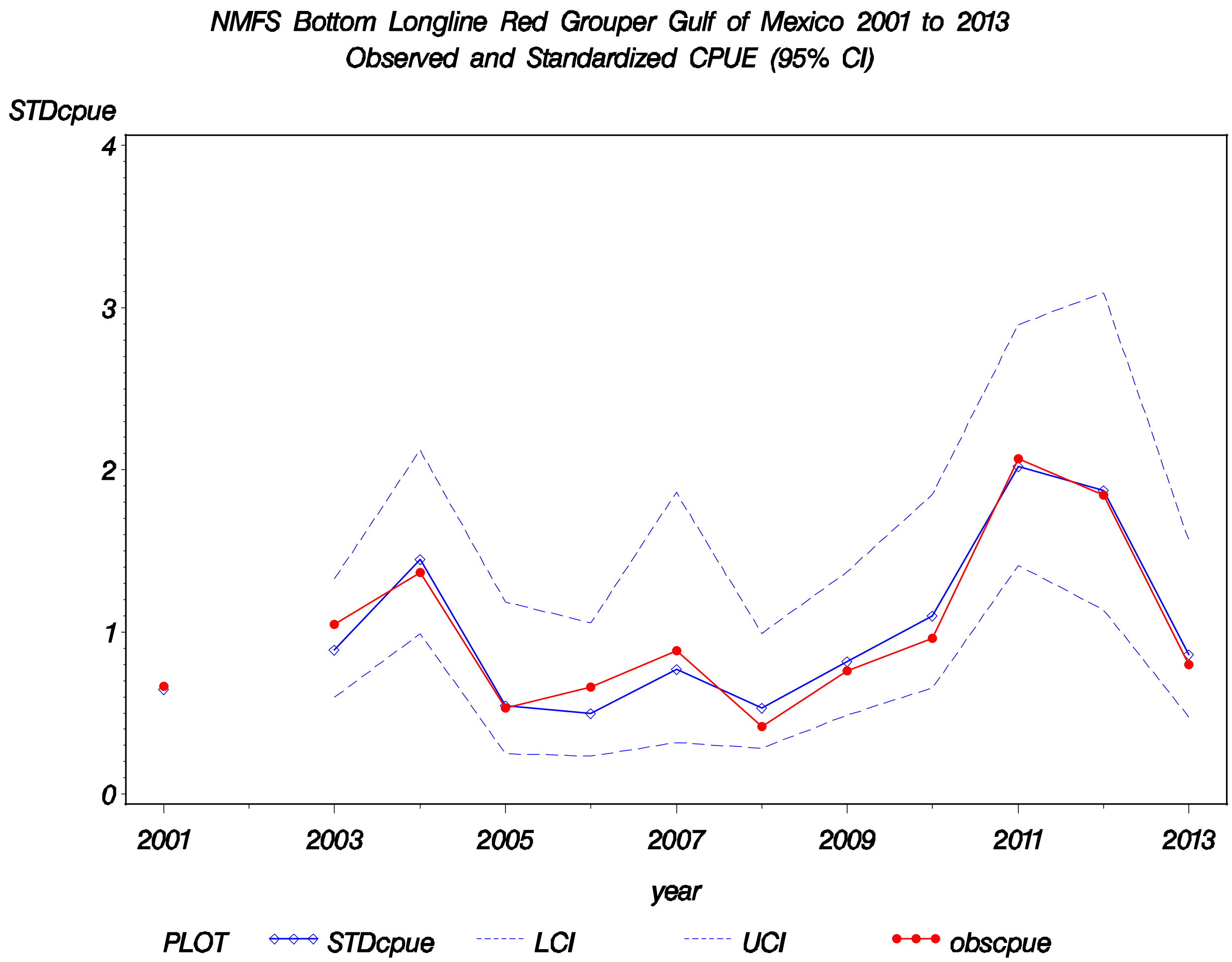


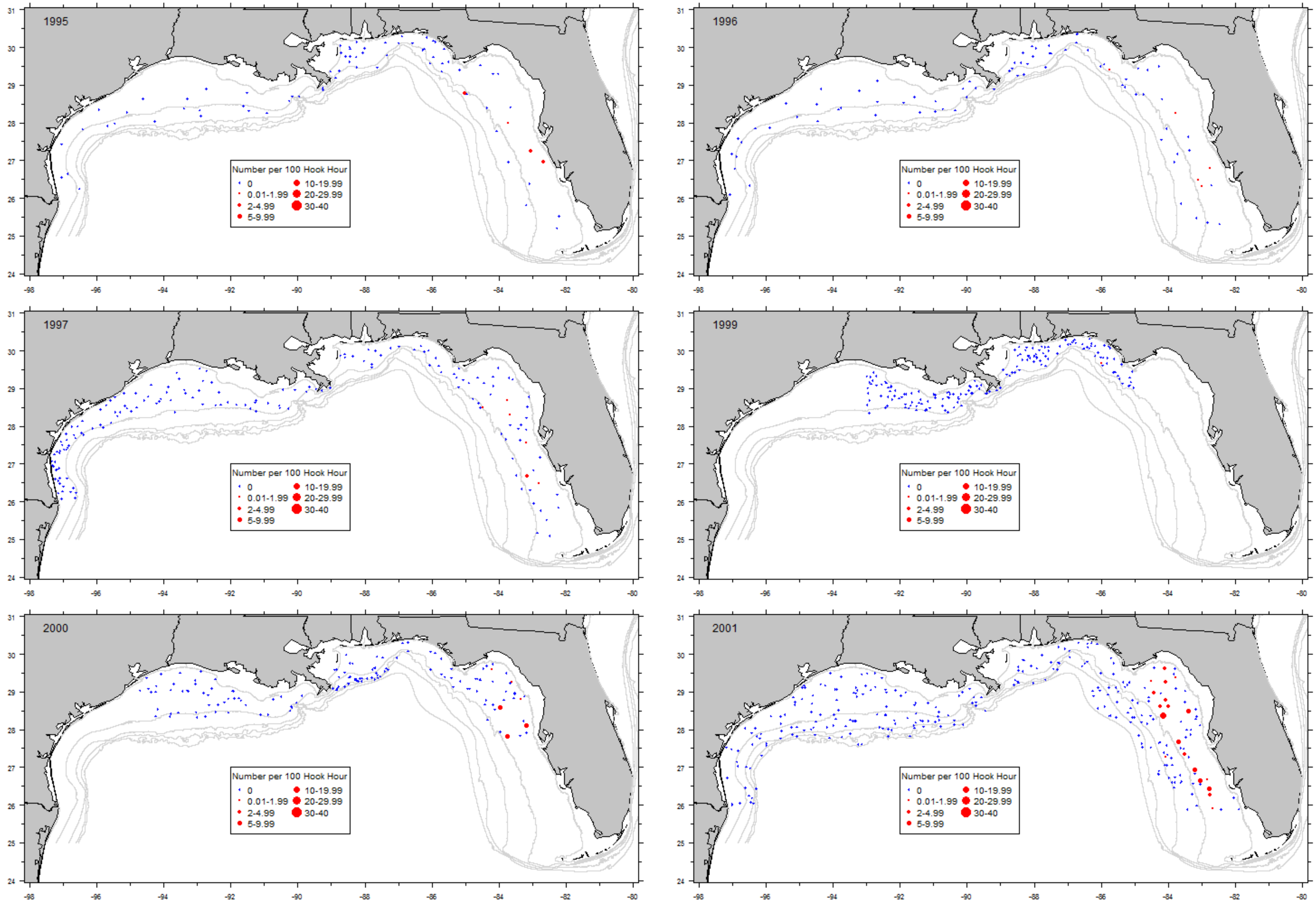
Figure 8. Annual index of abundance for red grouper from the NMFS Bottom Longline Surveys from 2001 – 2013.

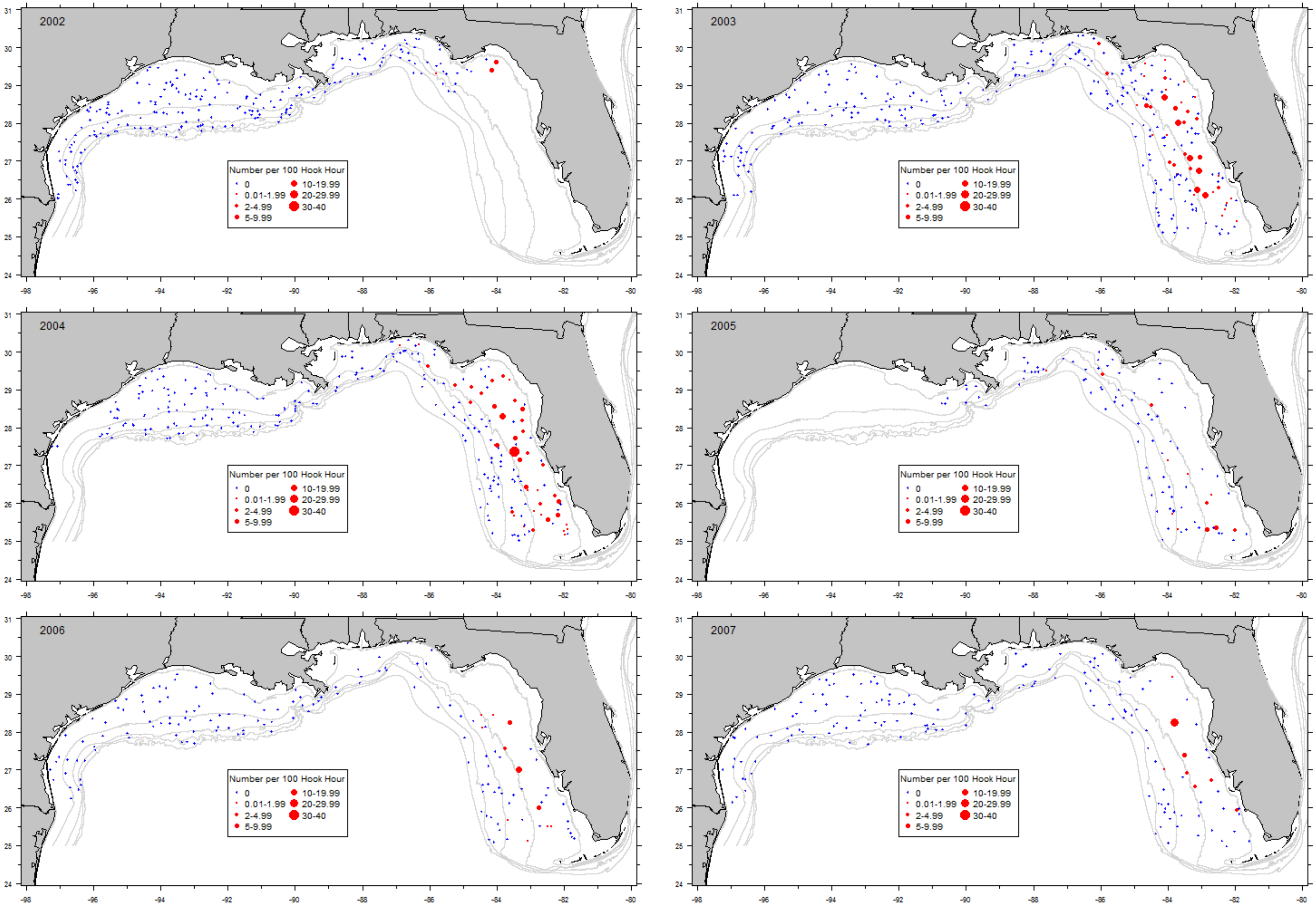
Appendix

Appendix Table 1. Summary of the factors used in constructing the red grouper abundance index from the NMFS bottom longline survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2001	93	20	0.21505	0.87628
Year	2003	117	40	0.34188	1.38033
Year	2004	98	41	0.41837	1.80487
Year	2005	40	10	0.25000	0.70350
Year	2006	39	11	0.28205	0.87280
Year	2007	42	8	0.19048	1.16871
Year	2008	60	16	0.26667	0.55240
Year	2009	63	22	0.34921	1.00165
Year	2010	67	22	0.32836	1.26605
Year	2011	122	49	0.40164	2.73074
Year	2012	49	23	0.46939	2.43430
Year	2013	47	16	0.34043	1.05748
Area	Northern	210	44	0.20952	0.52172
Area	Central	287	128	0.44599	2.41659
Area	Southern	340	106	0.31176	1.20946
Time of day	Day	410	151	0.36829	1.81270
Time of day	Night	427	127	0.29742	1.10335

Appendix Figure 1. Annual survey effort and catch of red grouper from the NMFS bottom longline survey (1995-2013).




2002
2003
2004
2005
2006
2007
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
31
30
29
28
27
26
25
24
-98
-96
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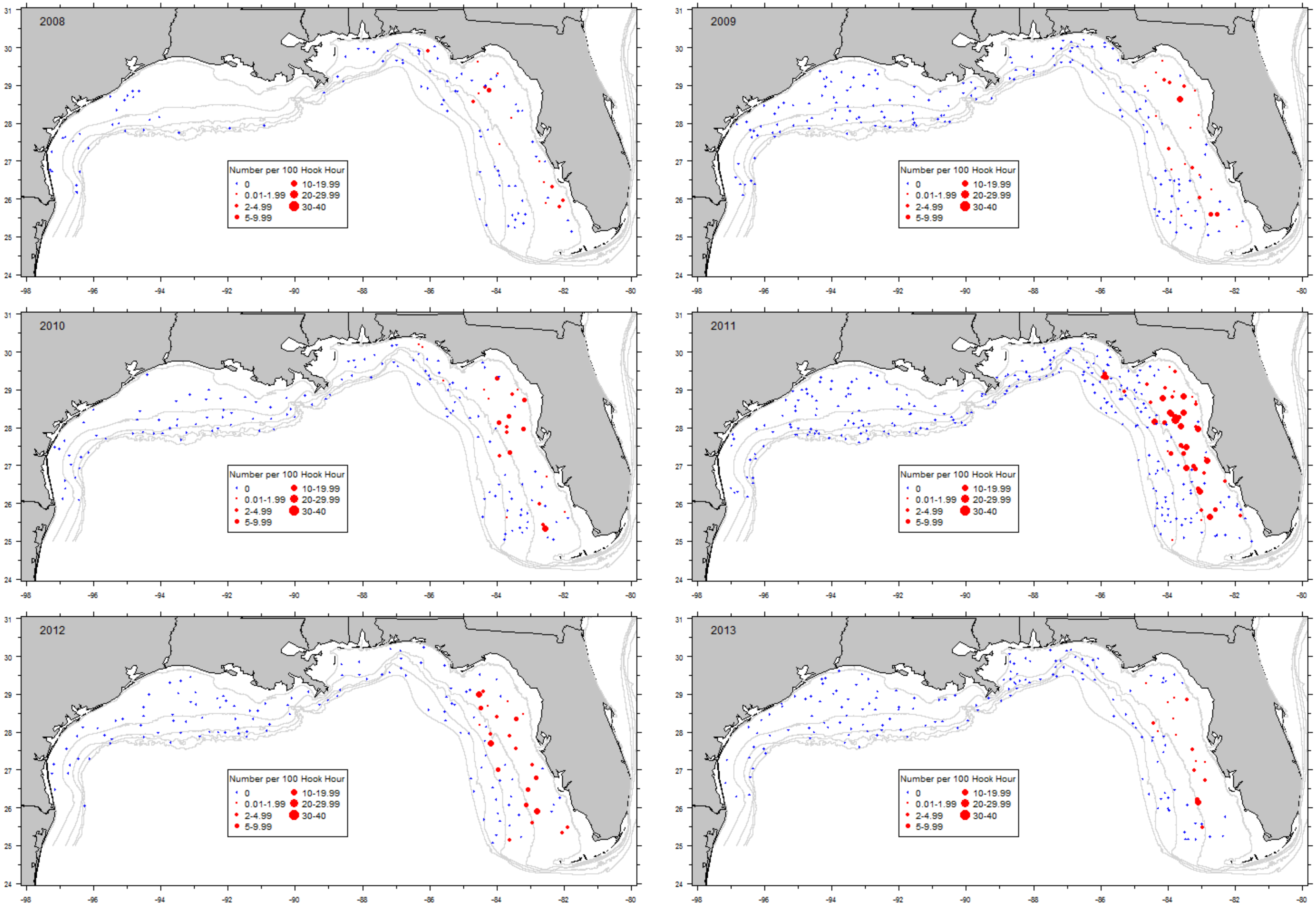
-90
-88
-86
-84
-82
-80


2008
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
2009
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
2010
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
2011
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
2012
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
2013
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-29.99
30-40
31
30
29
28
27
26
25
24
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80