An Index of Relative Abundance for Red Grouper Captured During the NMFS Bottom Longline Survey in the Northern Gulf of Mexico

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An Index of Relative Abundance for Red Grouper Captured During the NMFS Bottom Longline Survey in the Northern Gulf of Mexico

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Abstract: *The Oceanic and Coastal Pelagics Branch within the Southeast Fisheries Science Center (SEFSC) has conducted standardized bottom longline surveys in the Gulf of Mexico and U.S. South Atlantic Ocean since 1995. In addition to the annual survey, in 2011, the Congressional Supplemental Sampling Program (CSSP) was conducted, where increased levels of standardized bottom longline survey effort were maintained from April through October of that year. Data from the SEFSC Bottom Longline Survey and the CSSP Survey have been used during previous assessments of red grouper (Epinephelus morio). This paper provides a new abundance index through 2022 for red grouper for the upcoming assessment.*

Introduction

The National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), Oceanic and Coastal Pelagics (OCP) Branch has conducted standardized bottom longline (BLL) surveys in the western North Atlantic Ocean (Atlantic), including the northern Gulf of Mexico (GOM) 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, groupers, and tilefishes. The evolution of these surveys has been descried in Ingram *et al*. (2005) and will not be described again in this document.

In 2011, the Congressional Supplemental Sampling Program (CSSP) focused on completing monthly gulfwide bottom longline surveys in the U.S. northern GOM from April through October (for a full review of the CSSP see Campbell *et al.* 2012). Sampling during the CSSP program was conducted using the same gear as the NMFS SEFSC BLL survey and a similar survey design. The primary differences between the two surveys were in the depth range of coverage and the proportion of stations allocated to each depth strata. The NMFS SEFSC BLL survey samples in depths ranging from 9 to 366 m with 50% of samples in depths of 9 to 55 m, 40% of samples in depths of 55 to 183 m and 10% of samples in depths of 183 to 366 m, with samples allocated to defined longitude/latitude divisions within each depth strata by the proportion of spatial area in each division. In contrast, the CSSP survey sampled depths from 9 to 400m with samples allocated proportionally by the spatial area of 38 strata based on longitude/latitude divisions and 3 depth strata (9 to 55 m, 55 to 183 m and 183 to 400 m). The purpose of this document is to provide an abundance index for red grouper (*Epinephelus morio*) using the combined survey data.

Methodology

Survey Design

The basic sample design utilizes a proportional allocation of stations based on the surface area of the continental shelf within NMFS statistical zones and depth zones. NMFS bottom longlines have maintained a standard configuration over the time series with the exception of hook type. Bottom longlines initially fished J-hooks when the survey began in 1995; a mixture of J-hooks and 15/0 circle hooks were utilized between 1999 and 2000; and 15/0 circle hooks were utilized exclusively beginning in 2001. Details concerning the methods and evolution of the NMFS SEFSC BLL have been covered in previous documents (Ingram *et al*. 2005).

Data

Data for the annual BLL survey were obtained from the SEFSC OCP Branch and the CSSP data were obtained from SEFSC OCP Branch Oracle database. Data from the CSSP were used to fill in gaps in the annual BLL survey due to vessel breakdowns and weather delays in 2011. Only CSSP data from the August survey were used for the eastern GOM (east of 88°N) and only data from the September survey was used for the western (west of 93°N) and central (between 88°N and 93°N) GOM to not over represent any one area of the GOM. These time frames historically match up with when the annual SEFSC BLL survey within those areas. For this document, the combined dataset will be hereafter referred to as NMFS BLL. Age data were obtained from the SEFSC Biology and Life History Branch. Details concerning the ageing methods used for red grouper can be found in Lombardi-Carlson (2014).

Data Exclusions

We used the time series of data between 2001 and 2022 to develop red grouper abundance indices (Table 1). Data from 1995 – 2000 was not used due to the use of J-type hooks, which caught relatively few red grouper (53) and the inconsistent survey design. When the hook type was changed to circle-hooks, red grouper catch increased by an order of magnitude (Ingram *et al*. 2005). Survey data from 2002 was dropped from the analysis because of the limited spatial coverage in the eastern GOM (Appendix Figure 1). Sampling was limited in 2020 due to the COVID pandemic and two hurricanes, however since the survey covered the core region of red grouper distribution, it was included in the dataset.

Data was limited spatially to an area east of 87°W, since few red grouper (4) had been captured west of this longitude. Depth was also used to truncate the data, with no stations deeper than 118 m being used, since there were no records of red grouper being captured any deeper. In 2005, sampling was done in late October and November (43 stations), outside the normal timeframe of the annual survey as half of the survey was canceled due to Hurricane Katrina. However, there was little temporal overlap during these months in other years (17 stations in 2004), so all stations conducted outside of August and September were removed. An exception was made in 2022, with data from early October being kept in the model due to these days being continuous with the usual end of the survey (i.e. Sept 30). After limiting the data, 1,209 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 and 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) $$p = \frac{e^{\mathbf{X\beta+\varepsilon}}}{1+e^{\mathbf{X\beta+\varepsilon}}},$$

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 III 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 considered for inclusion in the submodels were:

Submodel Variables (GOM)

Year: 2001, 2003 – 2022
Depth: 9 – 118 m (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

Distribution, Size and Age

The spatial distribution of red grouper collected during NMFS BLL sets is presented in Figure 1, with annual abundance and distribution presented in Appendix Figure 1. There were between 23 to 327 red grouper captured per year (Table 2), with 1,495 red grouper captured between 2001 and 2022. Of the 1,495 red grouper captured, 1,433 were measured with an average fork length of 502 mm (± 109 mm SD). Figure 2 shows the length frequency distribution of red grouper captured in the GOM. Otolith aging data from the SEFSC Biology and Life History Branch indicated the average age of red grouper collected on bottom longlines was 6.28 years (± 2.88 years SD) (Figure 3).

Abundance Index

The final delta-lognormal NMFS BLL index of red grouper abundance retained year, area, time of day and depth in the binomial submodel, and year and area in the lognormal submodel. A summary of the factors used in the model is presented in Appendix Table 1. Table 3 summarizes the 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 5,640.3 and 907.3, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figure 4, and indicate the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 4 and Figure 5.

Literature Cited

Bradu, D. and Y. Mundlak. 1970. Estimation in Lognormal Linear Models. *Journal of the American Statistical Association* 65:198-211.

Campbell, M., A. Pollack, T. Henwood, J. Provaznik and M. Cook. 2012. Summary report of the red snapper (*Lutjanus campechanus*) catch during the 2011 Congressional Supplemental Sampling Program (CSSP). SEDAR31-DW17.

Ingram, W., T. Henwood, M. Grace, L. Jones, W. Driggers, and K. Mitchell. 2005. Catch rates, distribution and size composition of large coastal sharks collected during NOAA Fisheries Bottom Longline Surveys from the U.S. Gulf of Mexico and U.S. Atlantic Ocean. LCS05/06-DW-27

Lo, N.C.H., 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 Science* 49:2515-2526.

Lombardi-Carlson, L. 2014. An age and growth description of red grouper (*Epinephelus morio*) from the northeastern Gulf of Mexico: 1978-2013 for SEDAR42 SEDAR42-DW-10. SEDAR, North Charleston, SC. 37 pp

Ortiz, M., C.M Legault and N.M. Ehrhardt. 2000. An alternative method for estimating bycatch from the U.S. shrimp trawl fishery in the Gulf of Mexico, 1972-1995. *Fishery Bulletin* 98:583-599.

Pennington, M. 1983. Efficient Estimators of Abundance, for Fish and Plankton Surveys. *Biometrics* 39:281-286.

Table 1. Summary of the total number of stations available for analysis (left) and the total number of stations used in the analysis (right). Areas within with the eastern Gulf of Mexico (east of 88°N) were delineated as Northern (north of 29°N), Central (between 27°N - 29°N), and Southern (south of 27°N) for use in the abundance index.

	Gulf of Mexico			
Year	East	Central	West	Total
2001	129	62	82	273
2002	42	71	98	211
2003	159	53	63	275
2004	135	60	36	231
2005	52			52
2006	61	37	50	148
2007	69	38	47	154
2008	75	7	26	108
2009	89	42	51	182
2010	84	31	30	145
2011	259	93	114	466
2012	73	35	33	141
2013	71	45	44	160
2014	61	29	27	117
2015	82	34	40	156
2016	84	31	38	153
2017	64	34	51	149
2018	73	36	39	148
2019	54	24	35	113
2020	36			36
2021	58	24	10	92
2022	66	29	33	128
Total	*1876*	*815*	*947*	*3638*

	Eastern Gulf of Mexico			
Year	Northern	Central	Southern	Total
2001	28	40	24	92
2002				
2003	28	39	48	115
2004	24	33	40	97
2005	3	12	25	40
2006	4	13	22	39
2007	13	9	19	41
2008	18	18	24	60
2009	14	19	29	62
2010	18	17	30	65
2011	33	48	41	122
2012	10	20	18	48
2013	13	15	15	43
2014	11	12	18	41
2015	18	16	17	51
2016	18	16	16	50
2017	12	14	18	44
2018	16	18	13	47
2019	9	14	16	39
2020	1	9	24	34
2021	11	10	16	37
2022	15	14	13	42
Total	*317*	*406*	*486*	*1209*

Table 2. Summary of the red grouper length data collected from the NMFS Bottom Longline Survey conducted between 2001 and 2022.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2001	92	83	79	290	837	502	112
2002							
2003	115	165	161	295	845	509	120
2004	97	173	169	290	786	496	103
2005	40	29	28	303	700	480	121
2006	39	34	32	370	669	520	87
2007	41	51	51	350	694	477	80
2008	60	33	31	275	800	548	132
2009	62	65	64	315	910	506	132
2010	65	85	79	320	810	501	107
2011	122	327	313	300	757	487	95
2012	48	123	110	320	749	508	89
2013	43	50	47	262	779	518	109
2014	41	23	23	376	779	536	117
2015	51	47	44	297	724	518	106
2016	50	27	27	257	789	533	143
2017	44	37	35	298	794	539	142
2018	47	26	25	325	727	468	116
2019	39	25	25	290	752	491	138
2020	34	28	28	357	788	512	108
2021	37	43	42	293	717	499	104
2022	42	21	20	357	769	517	109
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Mean Fork Length (mm)	Mean Standard Deviation (mm)
21	1209	1495	1433			502	109

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for red grouper index of relative abundance from 2001 to 2022.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 5640.3)*						*Lognormal Submodel Type 3 Tests (AIC 918.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	20	1181	36.64	1.83	0.0129	0.0140	20	338	2.67	0.0002
Depth	1	1181	68.05	68.05	<.0001	<.0001	1	338	0.86	0.3542
Area	2	1181	66.00	33.00	<.0001	<.0001	2	338	6.38	0.0019
Time of Day	1	1181	3.93	3.93	0.0473	0.0476	1	338	1.01	0.3164
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 5640.3)*						*Lognormal Submodel Type 3 Tests (AIC 909.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	20	1181	36.64	1.83	0.0129	0.0140	20	339	2.67	0.0002
Depth	1	1181	68.05	68.05	<.0001	<.0001	Dropped			
Area	2	1181	66.00	33.00	<.0001	<.0001	2	339	6.13	0.0024
Time of Day	1	1181	3.93	3.93	0.0473	0.0476	1	339	1.04	0.3082
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 5640.3)*						*Lognormal Submodel Type 3 Tests (AIC 907.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	20	1181	36.64	1.83	0.0129	0.0140	20	340	2.64	0.0002
Depth	1	1181	68.05	68.05	<.0001	<.0001	Dropped			
Area	2	1181	66.00	33.00	<.0001	<.0001	2	340	6.57	0.0016
Time of Day	1	1181	3.93	3.93	0.0473	0.0476	Dropped			

Table 4. Indices of red grouper abundance developed using the delta-lognormal (DL) model for 2001-2022. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per 100 hook 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	0.21739	92	0.76444	0.86948	0.28958	0.49292	1.53370
2002							
2003	0.33913	115	1.00372	1.14163	0.20571	0.75979	1.71535
2004	0.41237	97	1.58400	1.80163	0.19657	1.22052	2.65943
2005	0.25000	40	0.54233	0.61684	0.40946	0.28068	1.35563
2006	0.28205	39	0.51120	0.58144	0.39432	0.27183	1.24367
2007	0.19512	41	0.83984	0.95524	0.46607	0.39356	2.31854
2008	0.26667	60	0.56382	0.64129	0.32421	0.34076	1.20685
2009	0.35484	62	0.88542	1.00707	0.26534	0.59772	1.69676
2010	0.33846	65	1.21518	1.38214	0.26682	0.81803	2.33524
2011	0.40164	122	2.25557	2.56548	0.18224	1.78717	3.68275
2012	0.45833	48	2.26319	2.57415	0.26142	1.53927	4.30482
2013	0.34884	43	1.03380	1.17584	0.31811	0.63193	2.18789
2014	0.26829	41	0.57175	0.65031	0.38515	0.30909	1.36821
2015	0.25490	51	0.74332	0.84545	0.36005	0.42056	1.69958
2016	0.18000	50	0.33238	0.37804	0.43642	0.16401	0.87140
2017	0.31818	44	0.69629	0.79196	0.34286	0.40657	1.54266
2018	0.19149	47	0.42817	0.48699	0.42906	0.21403	1.10809
2019	0.20513	39	0.42945	0.48845	0.46242	0.20252	1.17809
2020	0.29412	34	0.61228	0.69640	0.40550	0.31913	1.51971
2021	0.21622	37	0.74702	0.84966	0.45357	0.35773	2.01806
2022	0.16667	42	0.44004	0.50051	0.48511	0.19957	1.25520

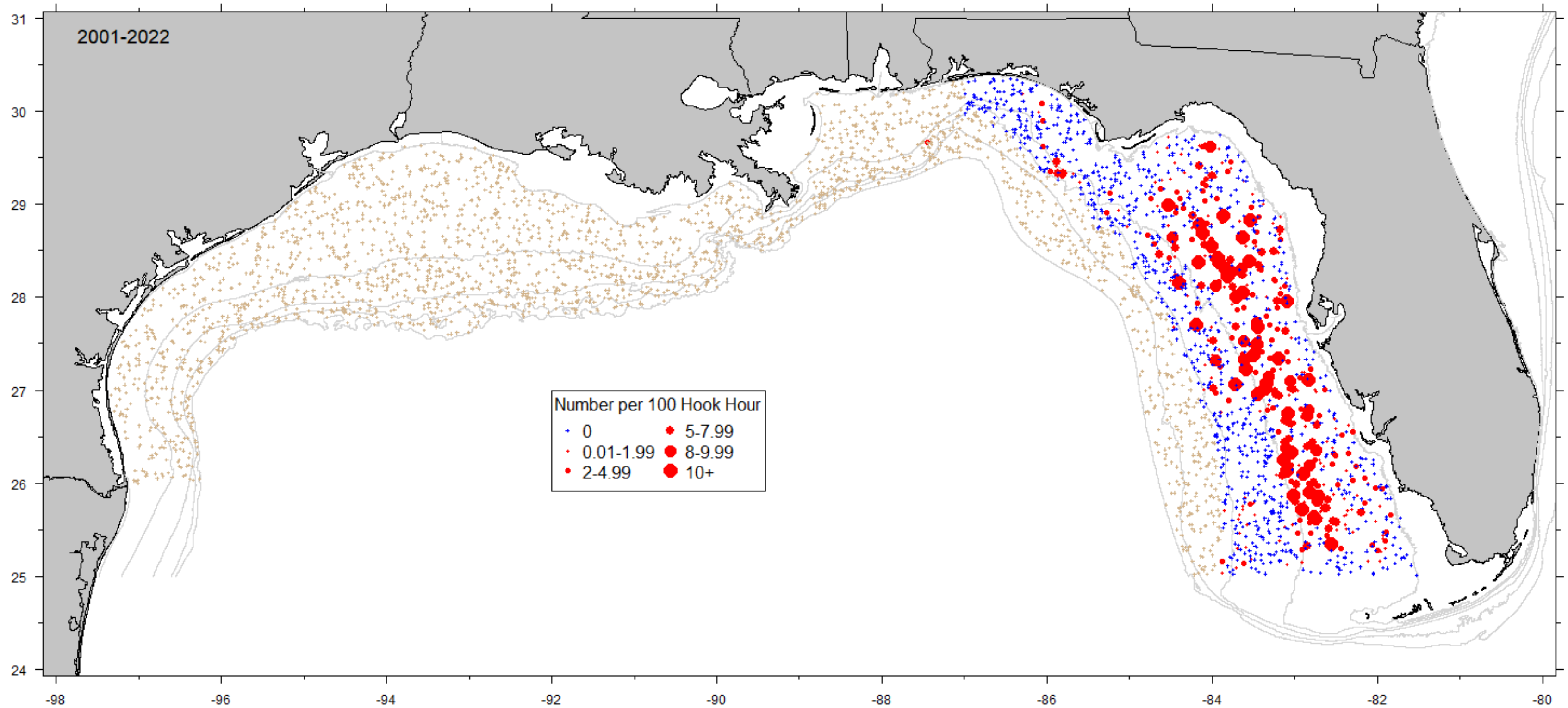


Figure 1. Stations sampled from 2001 to 2022 during the NMFS Bottom Longline Surveys with the catch per unit effort (CPUE, number per hook hour) for red grouper. Tan crosses represent stations not used in the analysis.

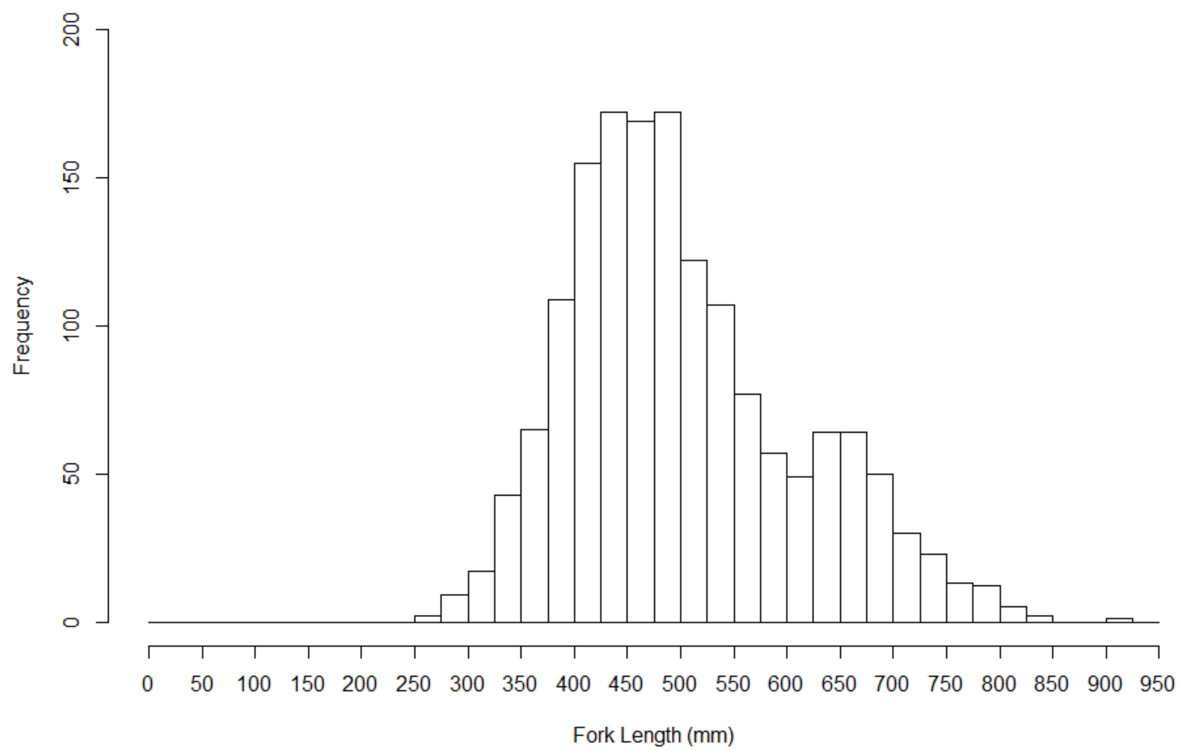


Figure 2. Length frequency histogram for red groupers captured in the Gulf of Mexico during the NMFS Bottom Longline Survey from 2001 - 2022.

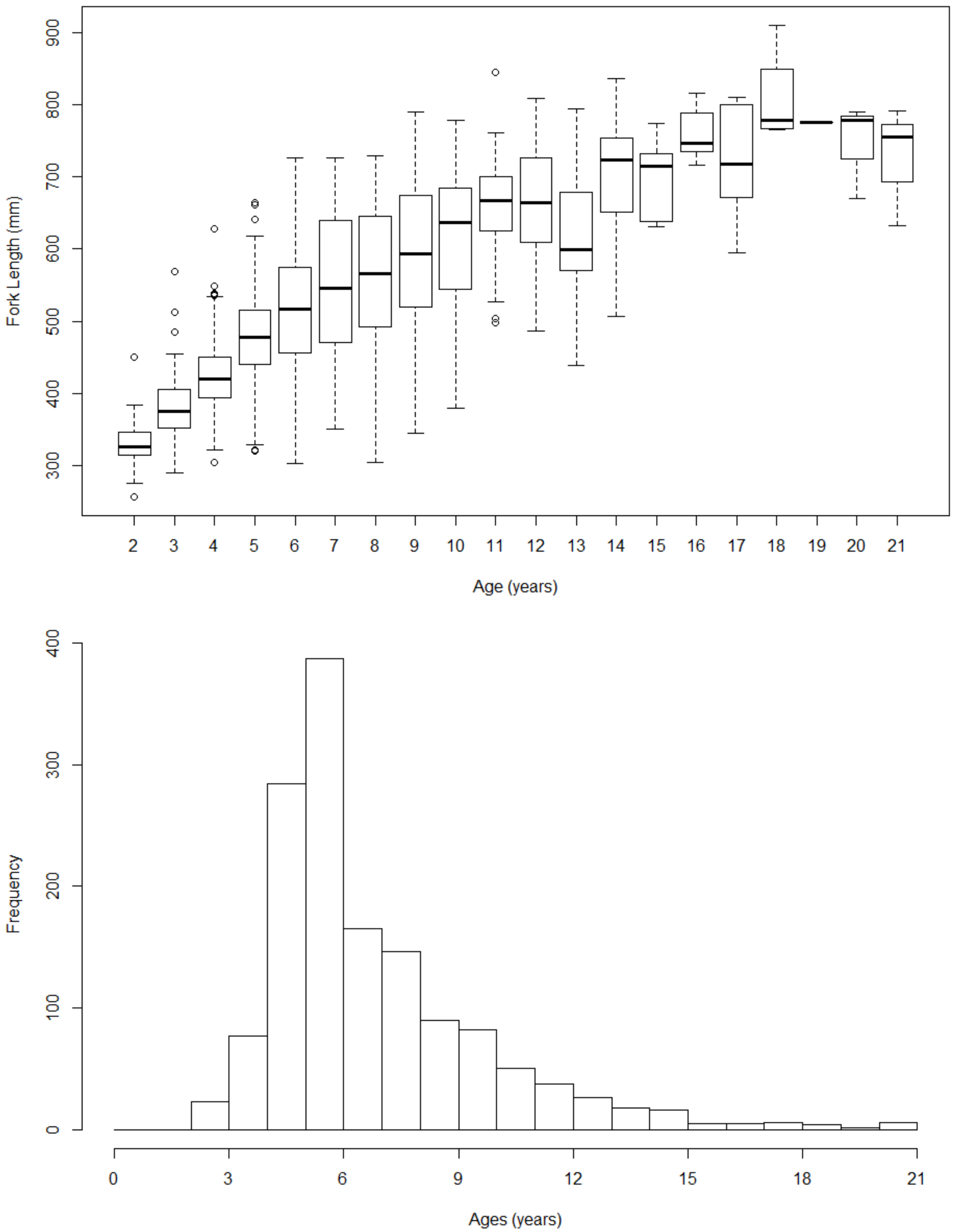


Figure 3. Length at age distribution of red grouper (n = 1,428) captured during the NMFS Bottom Longline Survey (top) and age distribution (bottom).

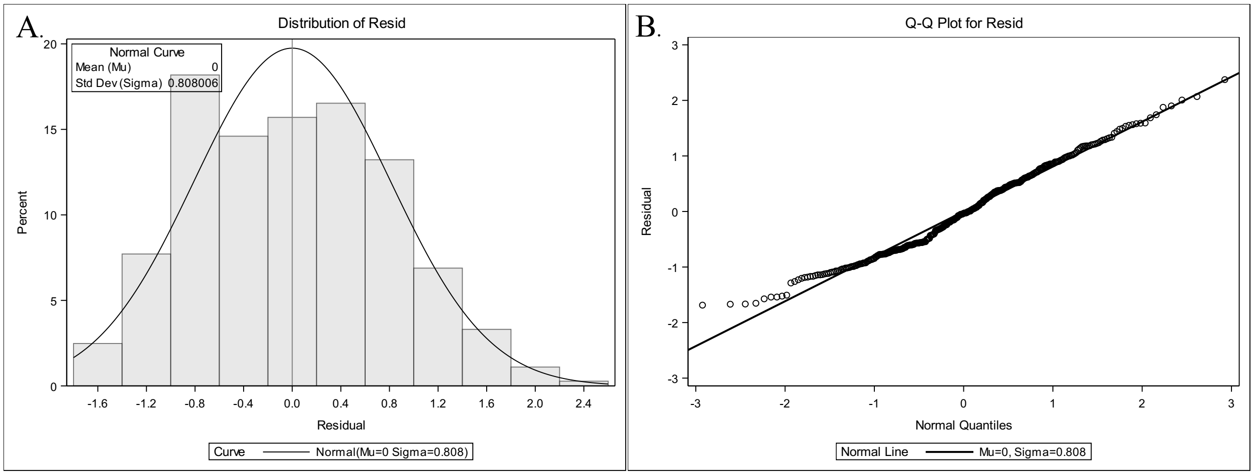


Figure 4. Diagnostic plots for lognormal component of the red grouper NMFS Bottom Longline Survey model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

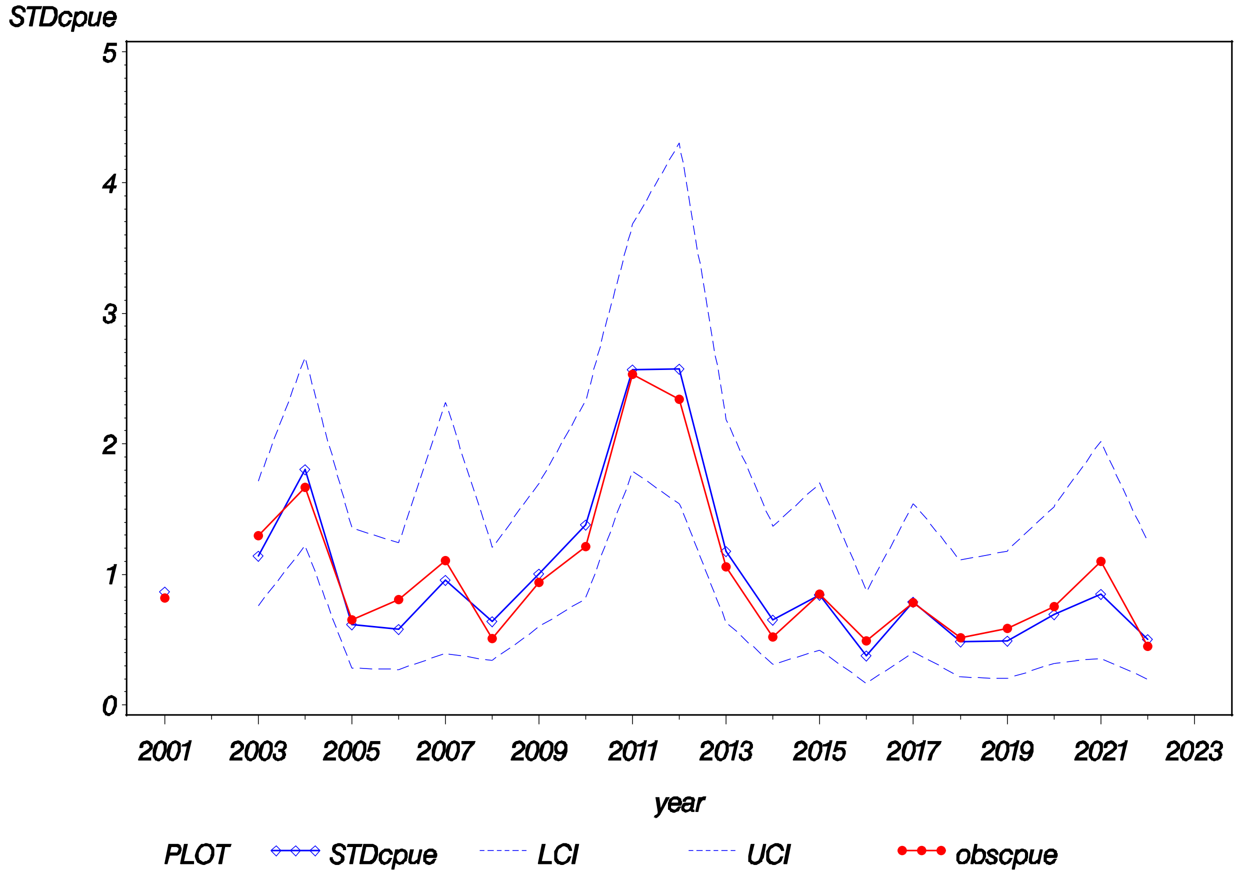


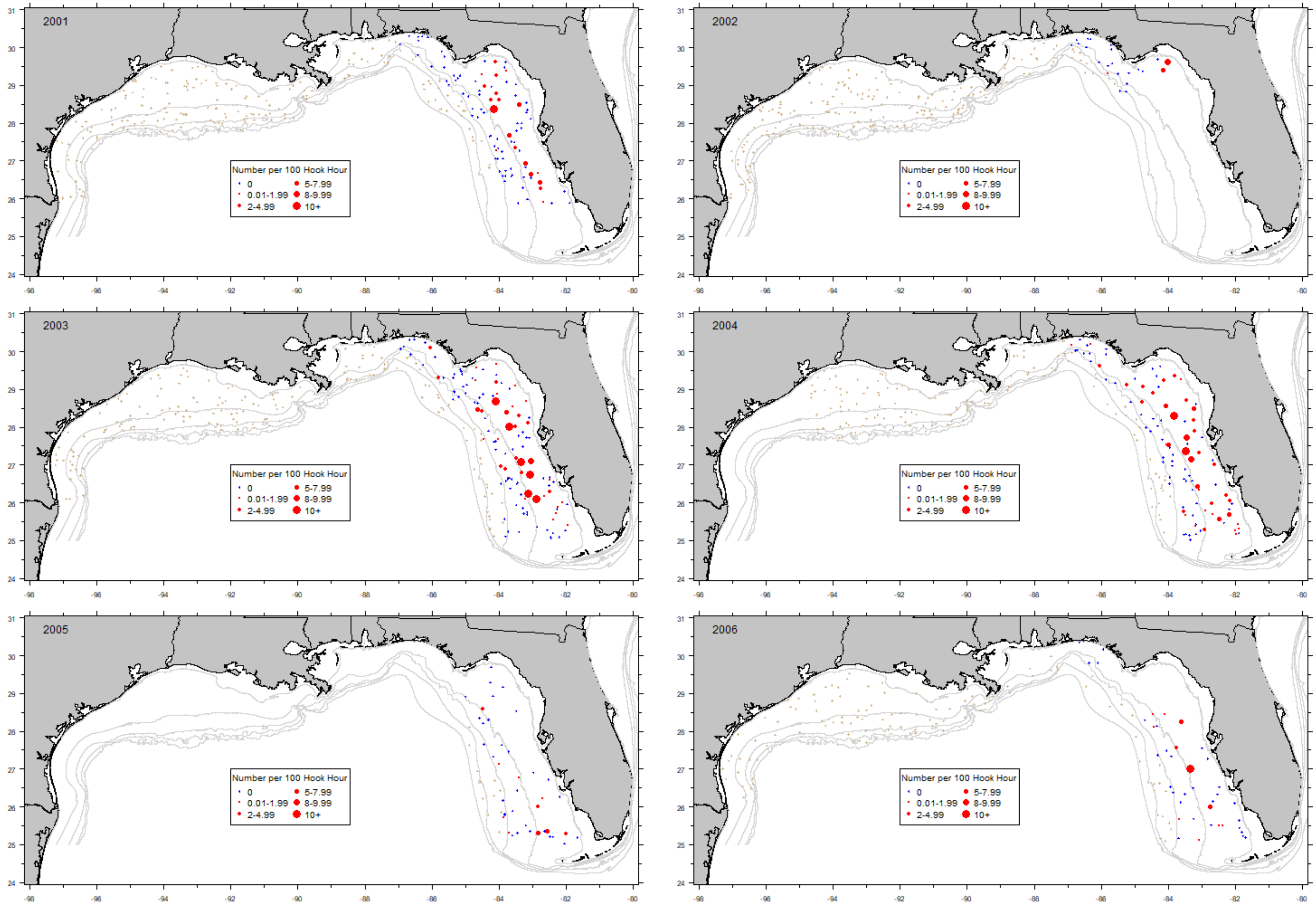
Figure 5. Annual index of abundance for red grouper from the NMFS Bottom Longline Survey from 2001 – 2022.

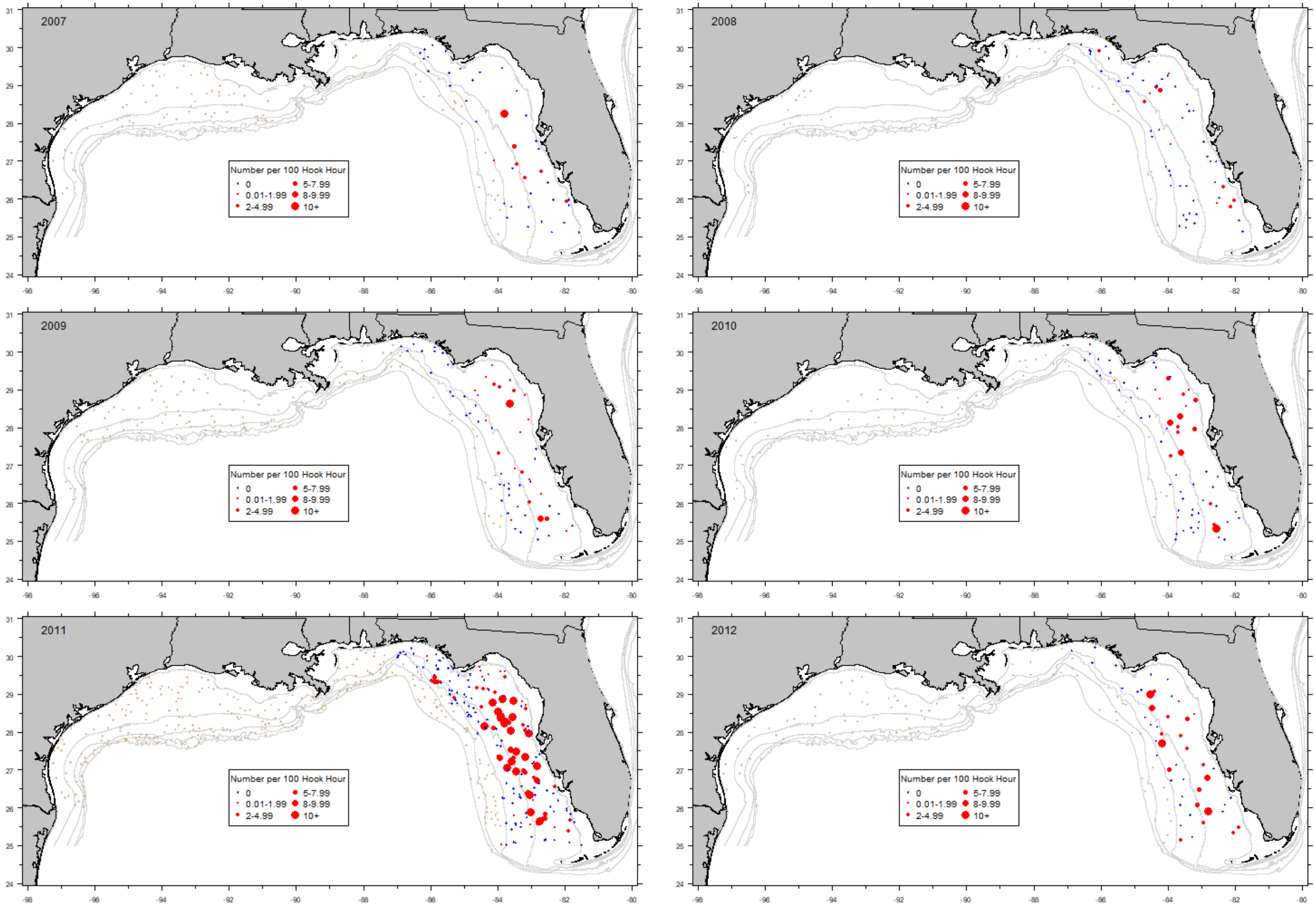
Appendix

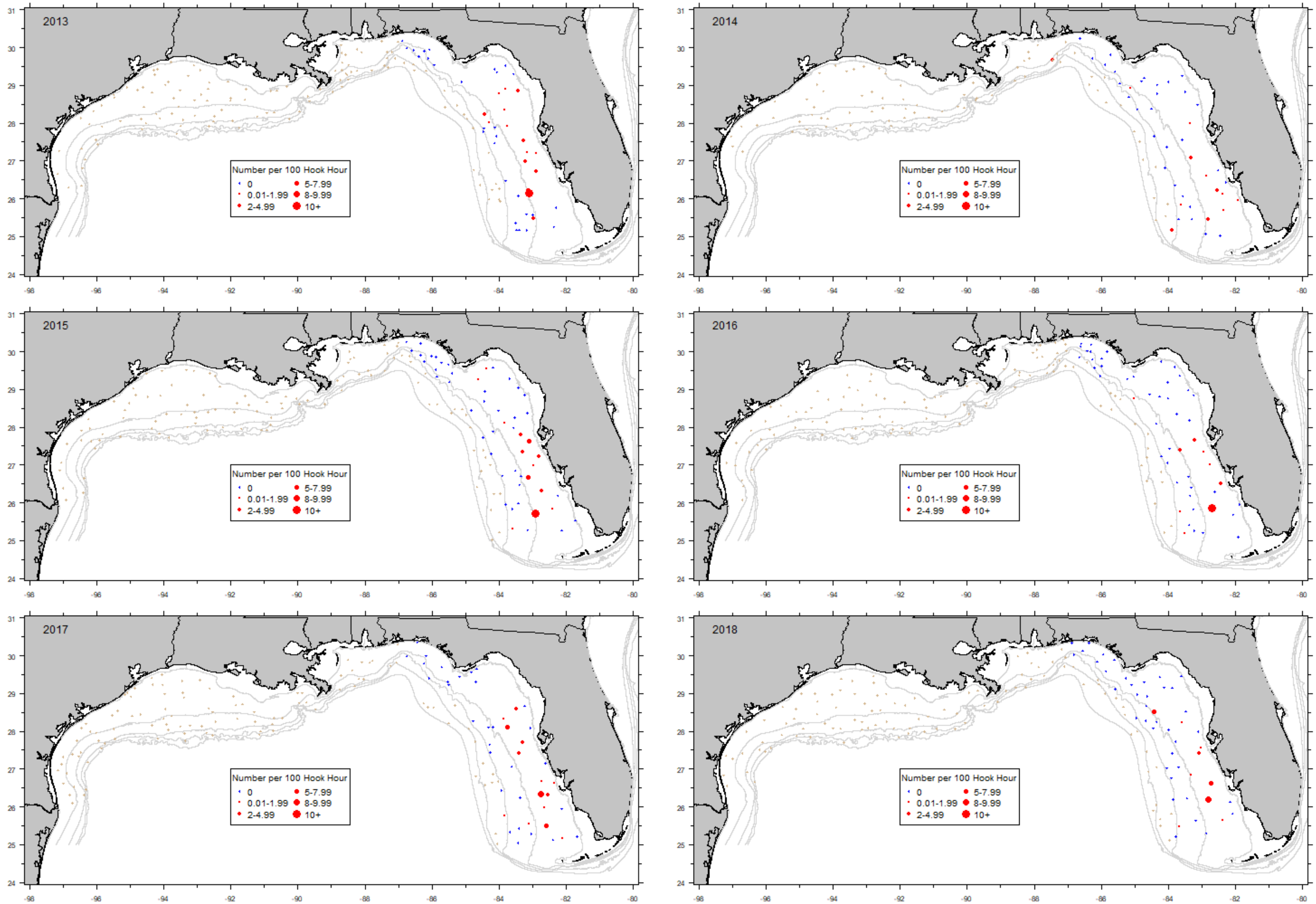
Appendix Table 1. Summary of the factors used in constructing the red grouper abundance index from the NMFS Bottom Longline Survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2001	92	20	0.21739	0.88795
Year	2003	115	39	0.33913	1.40067
Year	2004	97	40	0.41237	1.79875
Year	2005	40	10	0.25000	0.70350
Year	2006	39	11	0.28205	0.87280
Year	2007	41	8	0.19512	1.19721
Year	2008	60	16	0.26667	0.55240
Year	2009	62	22	0.35484	1.01702
Year	2010	65	22	0.33846	1.31060
Year	2011	122	49	0.40164	2.73241
Year	2012	48	22	0.45833	2.53124
Year	2013	43	15	0.34884	1.14453
Year	2014	41	11	0.26829	0.56204
Year	2015	51	13	0.25490	0.91904
Year	2016	50	9	0.18000	0.53281
Year	2017	44	14	0.31818	0.84554
Year	2018	47	9	0.19149	0.55387
Year	2019	39	8	0.20513	0.63616
Year	2020	34	10	0.29412	0.81436
Year	2021	37	8	0.21622	1.19034
Year	2022	42	7	0.16667	0.48514
Area	Northern	406	161	0.39655	1.98684
Area	Central	317	46	0.14511	0.35826
Area	Southern	486	156	0.32099	1.17377
Time of Day	Day	634	211	0.33281	1.49740
Time of Day	Night	575	152	0.26435	0.94144

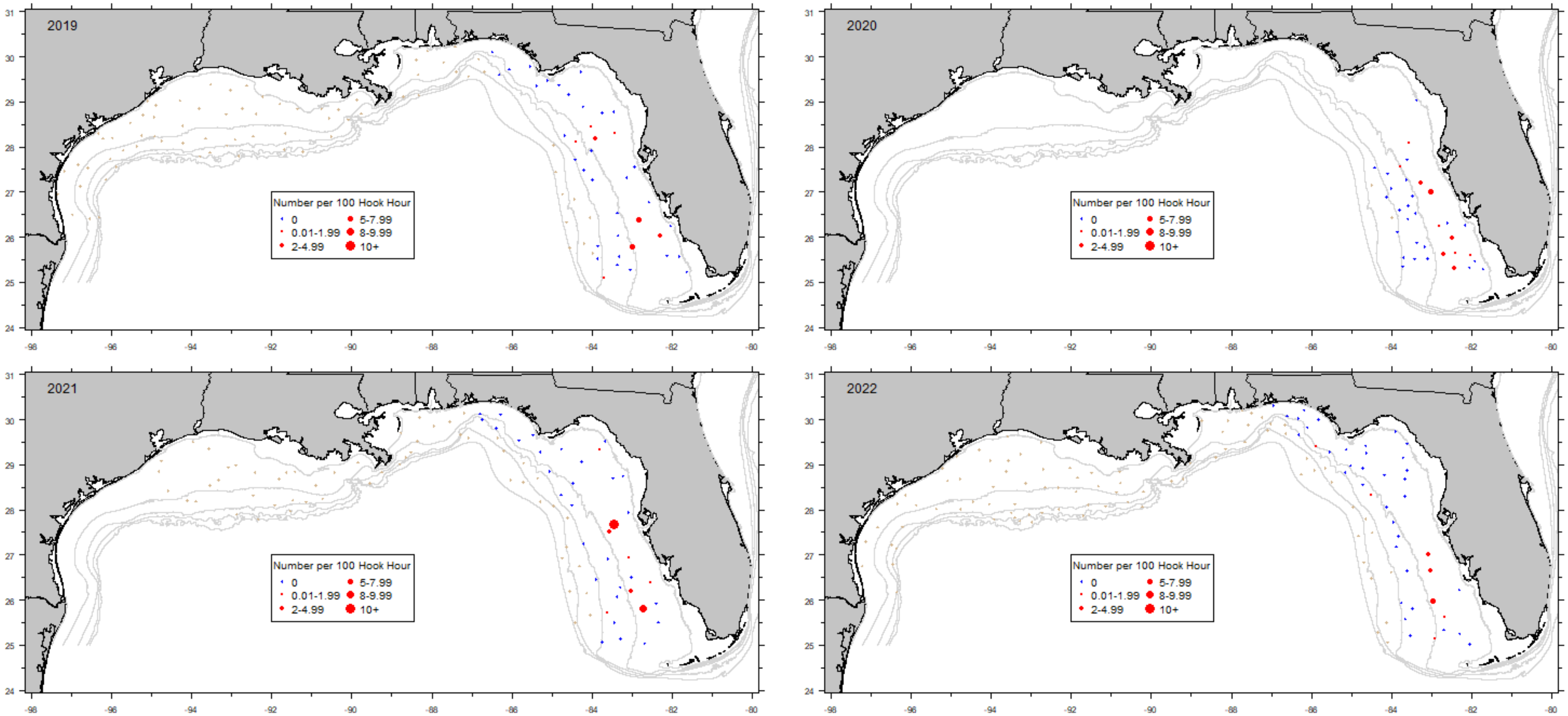
Appendix Figure 1. Annual survey effort and catch of red grouper from the NMFS Bottom Longline Surveys (2001-2022). Tan crosses represent stations not used in the analysis. Note that data from the CSSP Bottom Longline Survey was used to supplement data collected in 2011.




2007
2008
2009
2010
2011
2012
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+
31
30
29
28
27
26
25
24
-98
-96
-94
-92
-90
-88
-86
-84
-82
-80



2013
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+
2014
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+
2015
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+
2016
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+
2017
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+
2018
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+


2019
2020
2021
2022
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-7.99
8-9.99
10+