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Indices of Relative Abundance for Red Snapper from the SEFSC Bottom Longline Survey in the Northern Gulf of Mexico

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Abstract: *The Oceanic and Coastal Pelagics Branch of the Southeast Fisheries Science Center (SEFSC) of NOAA Fisheries has conducted bottom longline surveys in the western North Atlantic Ocean, including the Gulf of Mexico (GOM), since 1995. In addition to the annual survey, the Congressional Supplemental Sampling Program (CSSP) was conducted in 2011, where increased levels of standardized bottom longline survey effort were maintained from April through October in the GOM. Data from the SEFSC Bottom Longline Survey and the CSSP Survey have been used during previous assessments of red snapper (Lutjanus campechanus). Relative abundance indices are presented for the eastern, central, and western GOM from the SEFSC and CSSP data from 2001 to 2023 for the upcoming assessment.*

Introduction

The NOAA Fisheries, Southeast Fisheries Science Center (SEFSC), Population and Ecosystem Monitoring (PEM) Division, Oceanic and Coastal Pelagics (OCP) Branch has conducted standardized bottom longline (hereafter SEFSC BLL) surveys in the western North Atlantic Ocean (Atlantic), including the Gulf of Mexico (GOM) and Caribbean Sea, 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, since 2001, and provide an important source of fisheries independent information on federally managed species of sharks, snappers, groupers, and tilefishes.

In the GOM, the 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 within each division. The surveys have maintained a standard gear configuration over the time series with the exception of hook type. In the early years of the survey, bottom longlines initially fished #3 J-hooks; 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 SEFSC BLL survey have been covered in previous documents (e.g. Ingram et al. 2005).

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 SEFSC BLL survey, and a similar survey design. The primary differences between the SEFSC BLL and CSSP surveys were in the depth range of coverage and the proportion of longline sets allocated to each depth strata. The CSSP survey sampled depths from 9 to 400 m 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).

Red snapper (*Lutjanus campechanus*) captured during fishery-independent bottom longline surveys were first used to reflect trends in stock size for the western and eastern GOM during the Southeast Data Assessment and Review (SEDAR 7) Update Assessment process in 2009 (SEDAR Red Snapper Update, 2009). The data have since been incorporated into all of the subsequent red snapper stock assessments (SEDAR 31, SEDAR 52, and SEDAR 74) and their associated update assessments. Detailed information concerning iterations of the indices are documented in Henwood *et al.* (2005), Ingram and Pollack (2012), Pollack *et al.* (2017), and Pollack and Hanisko (2022). Based on the recommendations of the SEDAR 74 Stock Id Workshop (SEDAR 74 Stock ID 2021), the current assessment will be transitioning from a two-area model used in SEDAR 52 (2018) to a three-area model that was examined during the research track assessment for SEDAR 74 (2024).

This document outlines the development of red snapper abundance indices for the western GOM, central GOM, and eastern GOM (Figure 1), following the methods outlined in Pollack and Hanisko (2022) and recommendations from SEDAR 74 (2024).

Methodology

Data

Data for the annual SEFSC BLL survey and CSSP survey were obtained from an SEFSC ORACLE database. Sampling effort during the 2011 SEFSC BLL survey was limited in spatial coverage due to vessel breakdowns and weather delays. Therefore, we utilized data from the CSSP survey to supplement sampling effort from the SEFSC BLL survey in 2011. 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 snapper can be found in Garner *et al.* (2022).

Data Exclusions

The time series utilized to develop red snapper abundance indices were between 2001 and 2023 (Table 1). Based on the spatial distribution of sampling (mostly less than 55m) and the use of J hooks instead of circle hooks, which had significantly lower catch rates than circle hooks (Henwood *et al.* 2005), the years 1995 – 2000 were excluded from the analysis. In addition, depth was used to limit the data, with all sampling deeper than 183 m excluded since there were no records of red snapper being caught any deeper (183 m was chosen because it is the inner extent of the deepest depth zone in the survey design).

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 samples within those areas.

For the western GOM SEFSC BLL index, data from the years 2005 and 2008 were excluded due to extremely low sampling effort and limited spatial coverage (see Appendix Figure 1). Data from 2020 were not included for the western GOM SEFSC BLL index as no samples were taken due to restrictions in vessel time due to the COVID pandemic. For the central GOM indices, the years 2007 and 2008 were excluded because of the lack of positive captures. For the SEFSC BLL eastern GOM, no samples were taken in the area for 2002; additionally, 2008 and 2015 were excluded from the model because of the lack of positive captures.

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for red snapper (Bradu and Mundlak 1970, Pennington 1983). 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 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 (Western Gulf of Mexico – SEFSC BLL)

Year: 2001 – 2004, 2006 – 2007, 2009 – 2019, 2021 – 2023
Zone: 1 – 9 (Figure 1)
Depth: Continuous (9 – 183 m)
Time of Day: Day, Night

Submodel Variables (Central Gulf of Mexico – SEFSC BLL)

Year: 2001 – 2006, 2009 – 2019, 2021 – 2023
Zone: 10 – 14/15 (Figure 1)
Depth: Continuous (9 – 183 m)
Time of Day: Day, Night

Submodel Variables (Eastern Gulf of Mexico – SEFSC BLL)

Year: 2001, 2003 – 2007, 2009 – 2023
Zone: 14/15 – 18 (Figure 1)
Depth: Continuous (9 – 183 m)
Time of Day: Day, Night

Results and Discussion

Spatial Distribution, Size and Age

The spatial distribution of red snapper is presented in Figure 2 for the SEFSC BLL survey, with annual abundance and distribution presented in Appendix Figure 1. Annual catch and length summaries for the western GOM, central GOM, and eastern GOM data are presented in Tables 2a, 2b, and 2c, respectively. Length and age distribution for the SEFSC BLL indices are presented in Figures 3 and 4.

Abundance Index – Western Gulf of Mexico – SEFSC BLL

For the SEFSC BLL western GOM abundance index of red snapper, year, zone, and depth were retained in the binomial submodel, while year and time of day were retained in the lognormal submodel. 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 6,390.4 and 1,193.9, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figure 5 and indicated the distribution of the residuals was approximately normal. Annual abundance indices are presented in Table 4 and Figure 6.

Abundance Index – Central Gulf of Mexico – SEFSC BLL

For the SEFSC BLL central GOM abundance index of red snapper, year and zone were retained in the binomial submodel, while year was retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 2. Table 5 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 3,860.2 and 175.9, respectively. There was an increase in the AIC when zone was removed from the lognormal submodel (170.0 to 175.9), however since zone was not significant the final model run was deemed acceptable. The diagnostic plots for the binomial and lognormal submodels are shown in Figure 7 and indicated the distribution of the residuals was approximately normal. Annual abundance indices are presented in Table 6 and Figure 8.

Abundance Index – Eastern Gulf of Mexico – SEFSC BLL

For the SEFSC BLL eastern GOM abundance index of red snapper, year, zone and depth were retained in the binomial submodel, while only year was retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 3. Table 7 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 5,896.3 and 72.6, respectively. The diagnostic plots for the binomial and lognormal submodels are shown in Figure 9 and indicated the distribution of the residuals was approximately normal. Annual abundance indices are presented in Table 8 and Figure 10.

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Table 1. Summary of the total number of stations available for analysis by bottom longline zone per year. Note that based on regional boundaries, zones 14 and 15 are split between the central and eastern regions.

Year	Western									Central						Eastern					Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	14	15	16	17	18	
2001	10	13	14	17	23	18	14	9	6	9	9	11	16	5	5	14	6	20	21	6	246
2002	14	17	18	20	24	19	17	14	7	10	10	12	11	5							198
2003	8	12	12	13	15	13	12	10	5	10	7	12	15	8	3	10	8	21	26	31	251
2004		2	13	16	19	17	12	9	7	10	7	12	8	6	2	8	6	20	23	29	226
2005								4	3	5	6	4	10	2	1	6	1	5	10	21	78
2006	5	8	7	9	14	8	8	6	6	4	3	4	3			5	1	8	12	17	128
2007	5	8	6	11	12	12	9	5	2	4	4	6	8	2	1	2	3	6	9	17	132
2008	5	5	5	6						3	4	7	8	4	1	5	5	6	11	13	88
2009	6	8	8	9	15	10	9	8	3	8	5	6	8	3	2	7	4	7	17	18	161
2010	5	6	1	6	7	8	5	6	2	5	4	7	9	4	3	3	6	7	11	21	126
2011	5	7	9	15	16	10	7	6	5	11	9	11	22	8	2	14	14	16	21	30	238
2012	3	6	5	5	9	10	8	5	2	5	3	4	5	5		5	5	11	11	13	120
2013	3	6	6	11	13	11	5	5	2	14	7	8	5	2	2	4	3	10	9	11	137
2014		5	2	11	8	7	7	4	3	5	4	3	7	4	1	3	3	4	9	12	102
2015	4	7	6	8	10	7	6	7	1	7	7	10	9	3	2	5	4	11	10	11	135
2016	4	7	7	6	10	7	5	5	3	6	14	10	8	2	2	4	4	9	8	12	133
2017	7	10	7	11	11	7	7	4	3	6	4	5	5	3		3	5	7	9	14	128
2018	3	7	6	8	10	11	7	4	3	7	6	6	9	3	2	8	3	8	7	10	128
2019	3	7	6	8	7	6	4	5	2	4	3	5	5	3		4	4	6	8	12	102
2020															1		1	9	11	14	36
2021	2	2	4	5	9	5	6	3	3	5	4	5	6	2	2	3	2	5	10	9	92
2022	3	6	4	7	10	7	6	5	2	4	6	8	7	2	3	5	3	6	4	12	110
2023	3	7	6	8	9	8	5	5	3	3	4	2	6	4	2	3	6	10	9	10	113

Table 2a. Summary of the red snapper length data collected from SEFSC Bottom Longline Survey conducted between 2001 and 2023 in the western Gulf of Mexico.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2001	124	87	84	386	861	713	88
2002	150	76	75	380	890	746	95
2003	100	62	60	356	904	695	118
2004	95	63	61	442	865	665	115
2005							
2006	71	35	32	497	841	745	83
2007	70	41	40	355	920	704	99
2008	21	11	10	412	845	666	121
2009	76	75	32	420	880	677	117
2010	46	36	35	490	840	659	94
2011	80	131	127	367	850	641	111
2012	53	136	127	488	840	697	71
2013	62	139	131	542	829	692	61
2014	47	61	58	524	831	695	61
2015	56	231	220	418	866	686	76
2016	54	191	178	305	829	684	60
2017	67	320	304	435	841	690	62
2018	59	188	182	534	851	692	53
2019	48	197	173	365	855	674	71
2020							
2021	39	170	165	525	800	689	46
2022	50	193	185	463	818	687	46
2023	54	258	243	315	880	690	54
Total Number of Years 21	Total Number of Stations 1422	Total Number Collected 2701	Total Number Measured 2522			Overall Mean Fork Length (mm) 688	

Table 2b. Summary of the red snapper length data collected from SEFSC Bottom Longline Survey conducted between 2001 and 2023 in the central Gulf of Mexico.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2001	55	3	2	584	880	732	209
2002	48	2	2	618	746	682	91
2003	55	5	5	514	765	609	112
2004	45	2	2	526	680	603	109
2005	28	1	1	506	506	506	.
2006	14	1	1	825	825	825	.
2007	25	0					
2008	27	0					
2009	32	4	1	564	564	564	.
2010	32	11	11	460	810	612	115
2011	63	39	37	412	891	583	115
2012	22	15	12	483	857	725	104
2013	38	11	7	490	721	587	88
2014	24	13	9	534	845	737	89
2015	38	28	24	561	890	712	87
2016	42	50	50	463	825	688	75
2017	23	5	4	685	785	753	46
2018	33	14	13	686	850	759	53
2019	20	15	15	480	810	712	80
2020							
2021	24	11	11	726	821	771	35
2022	30	11	11	623	775	728	52
2023	21	1	1	760	760	760	.
Total Number of Years 22	Total Number of Stations 739	Total Number Collected 242	Total Number Measured 219			Overall Mean Fork Length (mm) 680	

Table 2c. Summary of the red snapper length data collected from SEFSC Bottom Longline Survey conducted between 2001 and 2023 in the eastern Gulf of Mexico.

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation
2001	67	1	1	620	620	620	.
2002							
2003	96	4	4	483	587	528	52
2004	86	5	5	496	570	536	31
2005	43	2	2	629	644	637	11
2006	43	1	1	740	740	740	.
2007	37	7	6	534	670	629	51
2008	40	0	6	480	682	597	88
2009	53	6	7	460	670	582	85
2010	48	7	16	449	670	562	68
2011	95	17	2	514	694	604	127
2012	45	2	10	655	697	673	16
2013	37	10	1	670	670	670	.
2014	31	1	5	426	791	627	141
2015	41	0	1	451	451	451	.
2016	37	6	2	430	513	472	59
2017	38	2	3	565	705	641	71
2018	36	2	6	472	737	627	100
2019	34	3	2	634	780	707	103
2020	35	6	6	418	750	669	126
2021	29	2	13	429	801	677	110
2022	30	8	4	483	587	528	52
2023	38	13	5	496	570	536	31
Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured			Overall Mean Fork Length (mm)	
22	1039	105	99			615	

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for red snapper index of relative abundance for the western Gulf of Mexico from 2001 to 2023.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 6393.8)*						*Lognormal Submodel Type 3 Tests (AIC 1211.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	1370	129.92	6.84	<.0001	<.0001	19	428	5.40	<.0001
Depth	1	1370	76.26	76.26	<.0001	<.0001	1	428	0.05	0.8247
Zone	8	1370	23.15	2.89	0.0032	0.0034	8	428	1.14	0.3357
Time of Day	1	1370	0.30	0.30	0.5820	0.5821	1	428	5.74	0.0171
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 6390.4)*						*Lognormal Submodel Type 3 Tests (AIC 1200.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	1371	129.91	6.84	<.0001	<.0001	19	429	5.51	<.0001
Depth	1	1371	76.22	76.22	<.0001	<.0001		Dropped		
Zone	8	1371	23.56	2.94	0.0027	0.0029	8	429	1.14	0.3322
Time of Day				Dropped			1	429	5.73	0.0171
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 6390.4)*						*Lognormal Submodel Type 3 Tests (AIC 1193.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	1371	129.91	6.84	<.0001	<.0001	19	437	5.51	<.0001
Depth	1	1371	76.22	76.22	<.0001	<.0001		Dropped		
Zone	8	1371	23.56	2.94	0.0027	0.0029		Dropped		
Time of Day				Dropped			1	437	6.27	0.0127

Table 4. Indices of red snapper abundance developed using the delta-lognormal (DL) model for 2001-2023 for the western Gulf of Mexico. 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 (Scaled Index), 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	0.20161	124	0.64179	0.28296	0.26035	0.16955	0.47224
2002	0.23333	150	0.49645	0.21888	0.22402	0.14061	0.34073
2003	0.20000	100	0.56263	0.24806	0.28663	0.14142	0.43514
2004	0.21053	95	0.68683	0.30282	0.28800	0.17219	0.53256
2005							
2006	0.18310	71	0.53141	0.23430	0.35390	0.11787	0.46574
2007	0.18571	70	0.57211	0.25224	0.35259	0.12720	0.50020
2008							
2009	0.30263	76	1.05497	0.46513	0.26217	0.27773	0.77897
2010	0.17391	46	0.52579	0.23182	0.46389	0.09587	0.56054
2011	0.31250	80	1.24189	0.54755	0.25091	0.33404	0.89751
2012	0.35849	53	2.40083	1.05852	0.27812	0.61321	1.82721
2013	0.35484	62	2.30174	1.01483	0.25331	0.61629	1.67110
2014	0.31915	47	1.63168	0.71940	0.30977	0.39269	1.31794
2015	0.44643	56	4.11565	1.81458	0.23184	1.14825	2.86758
2016	0.50000	54	3.42439	1.50980	0.22233	0.97303	2.34268
2017	0.62687	67	5.20485	2.29480	0.16600	1.65019	3.19122
2018	0.45763	59	3.00462	1.32473	0.22584	0.84801	2.06945
2019	0.50000	48	4.47327	1.97225	0.22791	1.25748	3.09332
2020							
2021	0.56410	39	4.21101	1.85662	0.23152	1.17556	2.93224
2022	0.44000	50	3.73434	1.64646	0.25770	0.99152	2.73401
2023	0.57407	54	4.54581	2.00423	0.19979	1.34931	2.97704

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for red snapper index of relative abundance for the central Gulf of Mexico from 2001 to 2023.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 3869.1)*						*Lognormal Submodel Type 3 Tests (AIC 176.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	659	36.78	1.94	0.0085	0.0098	19	55	0.91	0.5768
Depth	1	659	0.62	0.62	0.4321	0.4323	1	55	0.12	0.7293
Zone	4	659	39.43	9.86	<.0001	<.0001	4	55	2.07	0.0971
Time of Day	1	659	1.09	1.09	0.2965	0.2969	1	55	0.00	0.9756
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 3881.2)*						*Lognormal Submodel Type 3 Tests (AIC 175.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	662	36.58	1.93	0.0090	0.0104	19	56	0.93	0.5499
Depth				Dropped			1	56	0.12	0.7257
Zone	4	662	39.82	9.96	<.0001	<.0001	4	56	2.21	0.0801
Time of Day	1	662	1.22	1.22	0.2689	0.2693		Dropped		
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 3860.2)*						*Lognormal Submodel Type 3 Tests (AIC 170.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	663	37.17	1.96	0.0076	0.0088	19	58	0.94	0.5404
Depth				Dropped				Dropped		
Zone	4	663	40.33	10.08	<.0001	<.0001	4	58	1.99	0.1086
Time of Day				Dropped				Dropped		
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 3860.2)*						*Lognormal Submodel Type 3 Tests (AIC 175.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	663	37.17	1.96	0.0076	0.0088	19	62	0.84	0.6534
Depth				Dropped				Dropped		
Zone	4	663	40.33	10.08	<.0001	<.0001		Dropped		
Time of Day				Dropped				Dropped		

Table 6. Indices of red snapper abundance developed using the delta-lognormal (DL) model for 2001-2023 for the central Gulf of Mexico. 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 (Scaled Index), 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	0.03636	55	0.04729	0.17154	0.90295	0.03661	0.80368
2002	0.04167	48	0.03203	0.11619	0.90651	0.024686	0.54683
2003	0.05455	55	0.07411	0.26883	0.74712	0.07096	1.01846
2004	0.02222	45	0.03036	0.11012	1.24497	0.01590	0.76250
2005	0.03571	28	0.02562	0.09292	1.24442	0.01343	0.64306
2006	0.07143	14	0.04387	0.15915	1.25344	0.02279	1.11140
2007							
2008							
2009	0.09375	32	0.10067	0.36519	0.75299	0.09559	1.39523
2010	0.18750	32	0.36417	1.32104	0.51904	0.49738	3.50870
2011	0.22222	63	0.59583	2.16142	0.34721	1.10077	4.24405
2012	0.13636	22	0.32206	1.16829	0.74775	0.30810	4.43000
2013	0.07895	38	0.14599	0.52957	0.76061	0.13711	2.04541
2014	0.29167	24	0.60641	2.19980	0.47541	0.89186	5.42585
2015	0.23684	38	0.68336	2.47894	0.42965	1.08834	5.64633
2016	0.19048	42	0.74035	2.68569	0.46512	1.10832	6.50796
2017	0.17391	23	0.19275	0.69921	0.65484	0.21171	2.30926
2018	0.15152	33	0.33762	1.22473	0.58516	0.41372	3.62560
2019	0.20000	20	0.54323	1.97059	0.64038	0.61012	6.36469
2020							
2021	0.08333	24	0.23471	0.85143	0.90657	0.18089	4.00752
2022	0.10000	30	0.35140	1.27474	0.74024	0.33984	4.78157
2023	0.04762	21	0.04152	0.15062	1.24154	0.02183	1.03929

Table 7. Summary of backward selection procedure for building delta-lognormal submodels for red snapper index of relative abundance for the eastern Gulf of Mexico from 2001 to 2023.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 5936.1)*						*Lognormal Submodel Type 3 Tests (AIC 84.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	930	17.27	0.91	0.5713	0.5714	19	28	1.31	0.2526
Depth	1	930	1.37	1.37	0.2423	0.2426	1	28	0.03	0.8568
Zone	4	930	19.97	4.99	0.0005	0.0006	4	28	0.09	0.9844
Time of Day	1	930	1.42	1.42	0.2331	0.2334	1	28	0.44	0.5122
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 5952.9)*						*Lognormal Submodel Type 3 Tests (AIC 82.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	933	16.40	0.86	0.6306	0.6303	19	32	1.50	0.1536
Depth				Dropped			1	32	0.14	0.7080
Zone	4	933	18.48	4.62	0.0010	0.0011		Dropped		
Time of Day	1	933	1.29	1.29	0.2560	0.2562	1	32	0.58	0.4508
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 5896.3)*						*Lognormal Submodel Type 3 Tests (AIC 73.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	934	16.89	0.89	0.5971	0.5970	19	33	1.53	0.1393
Depth				Dropped				Dropped		
Zone	4	934	19.04	4.76	0.0008	0.0008		Dropped		
Time of Day				Dropped			1	33	0.60	0.4422
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 5896.3)*						*Lognormal Submodel Type 3 Tests (AIC 72.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	19	934	16.89	0.89	0.5971	0.5970	19	34	1.55	0.1308
Depth				Dropped				Dropped		
Zone	4	934	19.04	4.76	0.0008	0.0008		Dropped		
Time of Day				Dropped				Dropped		

Table 8. Indices of red snapper abundance developed using the delta-lognormal (DL) model for 2001-2023 for the eastern Gulf of Mexico. 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 (Scaled Index), 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	0.01493	67	0.01251	0.09880	1.16057	0.01558	0.6266
2002							
2003	0.02083	96	0.04320	0.34131	0.81980	0.08135	1.43191
2004	0.03488	86	0.07015	0.55415	0.66732	0.16462	1.8654
2005	0.02326	43	0.05203	0.41107	1.15534	0.06518	2.5926
2006	0.02326	43	0.02569	0.20295	1.15227	0.03229	1.2758
2007	0.05405	37	0.17190	1.35797	0.80408	0.33076	5.57525
2008							
2009	0.07547	53	0.11592	0.91578	0.57630	0.31380	2.6726
2010	0.10417	48	0.18382	1.45216	0.50176	0.56288	3.7464
2011	0.10526	95	0.18377	1.45176	0.36518	0.71544	2.9459
2012	0.04444	45	0.04954	0.39133	0.81440	0.09397	1.6296
2013	0.02703	37	0.29398	2.32244	1.14938	0.37060	14.5540
2014	0.03226	31	0.03555	0.28087	1.14752	0.04491	1.7566
2015							
2016	0.08108	37	0.17249	1.36269	0.65730	0.41105	4.5175
2017	0.05263	38	0.06516	0.51478	0.80929	0.12449	2.1287
2018	0.05556	36	0.05268	0.41620	0.82455	0.09856	1.7574
2019	0.05882	34	0.09442	0.74593	0.81187	0.17975	3.0956
2020	0.11429	35	0.26749	2.11316	0.54033	0.76793	5.8149
2021	0.06897	29	0.07939	0.62715	0.80674	0.15220	2.5843
2022	0.06667	30	0.27067	2.13825	0.81600	0.51234	8.9240
2023	0.10526	38	0.29130	2.30124	0.56297	0.80578	6.5721

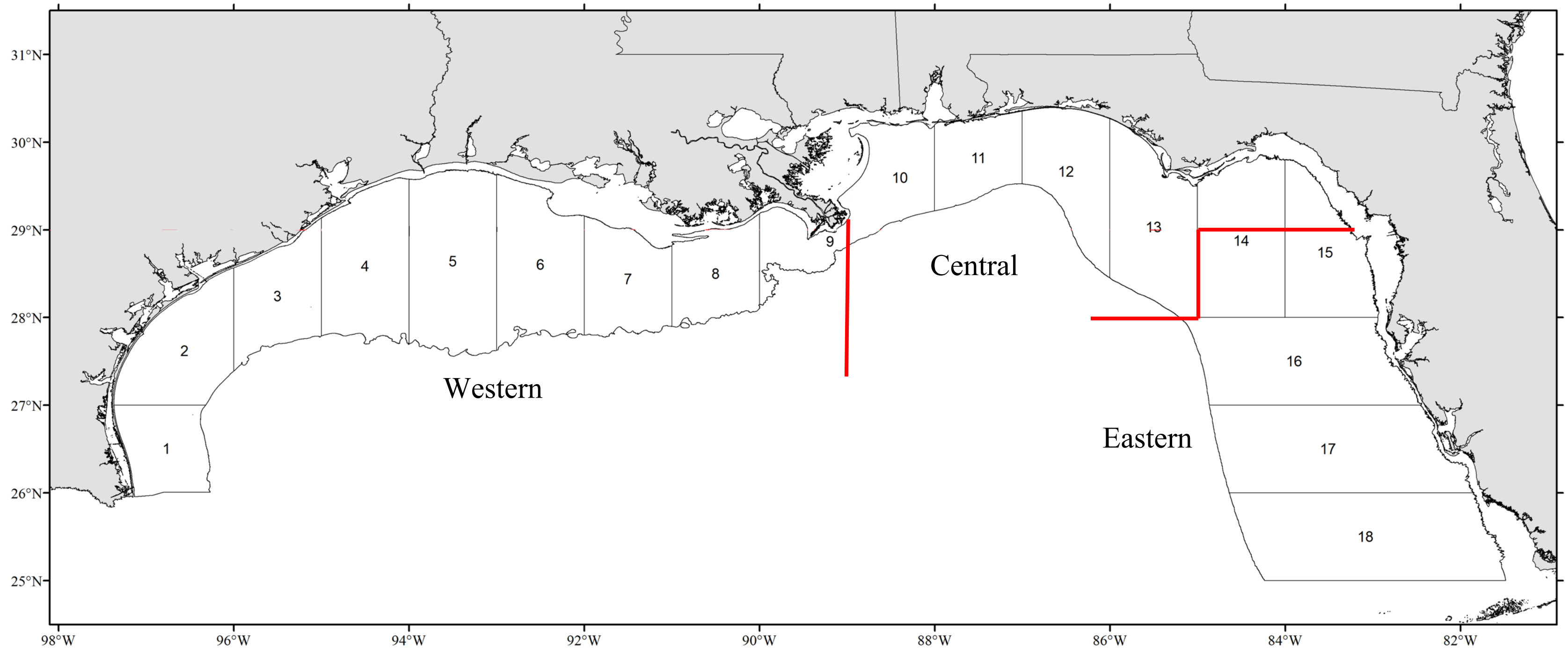


Figure 1. Breakdown of the zones within the Gulf of Mexico for the SEFSC Bottom Longline Survey. Red lines represent the boundaries for the three areas for which indices were produced according to the SEDAR 74 Stock ID Workshop (SEDAR 74 Stock ID 2021).

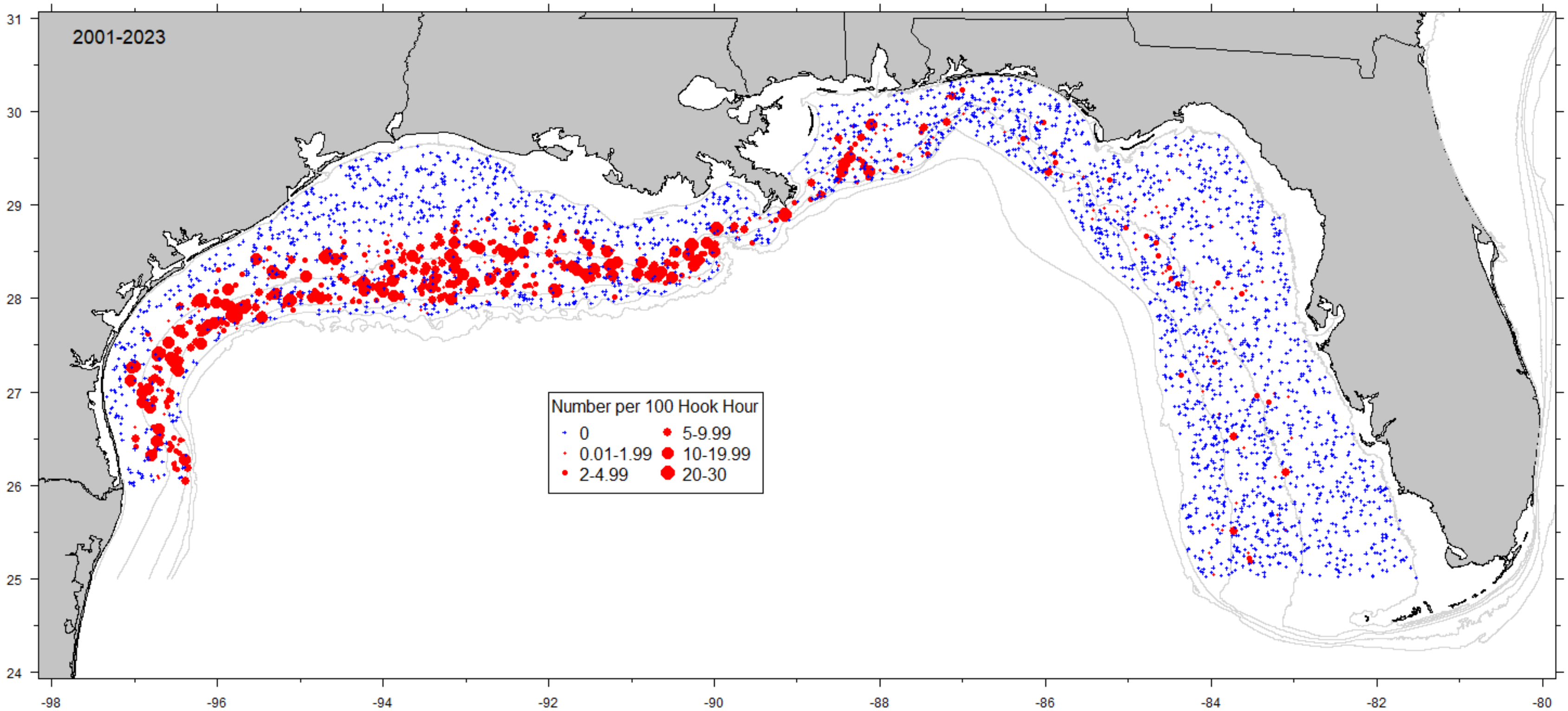


Figure 2. Stations sampled from 2001 to 2023 during the SEFSC Bottom Longline Survey with the catch per unit effort (CPUE, number per hook hour) for red snapper.

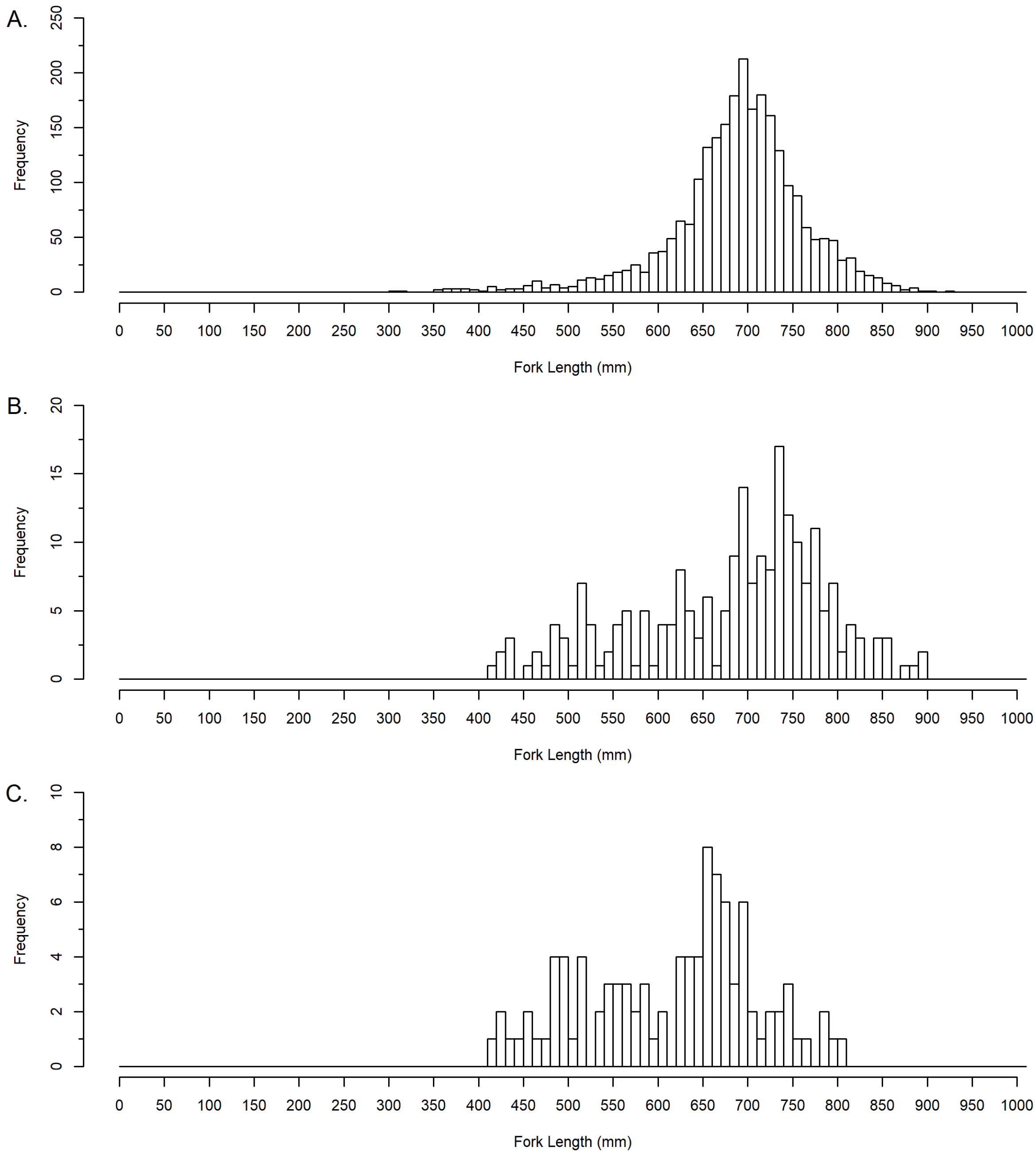


Figure 3. Length frequency histogram for red snapper captured during the SEFSC Bottom Longline Survey from 2001 to 2023 for the **A.** Western Gulf of Mexico, **B.** Central Gulf of Mexico, and **C.** Eastern Gulf of Mexico.

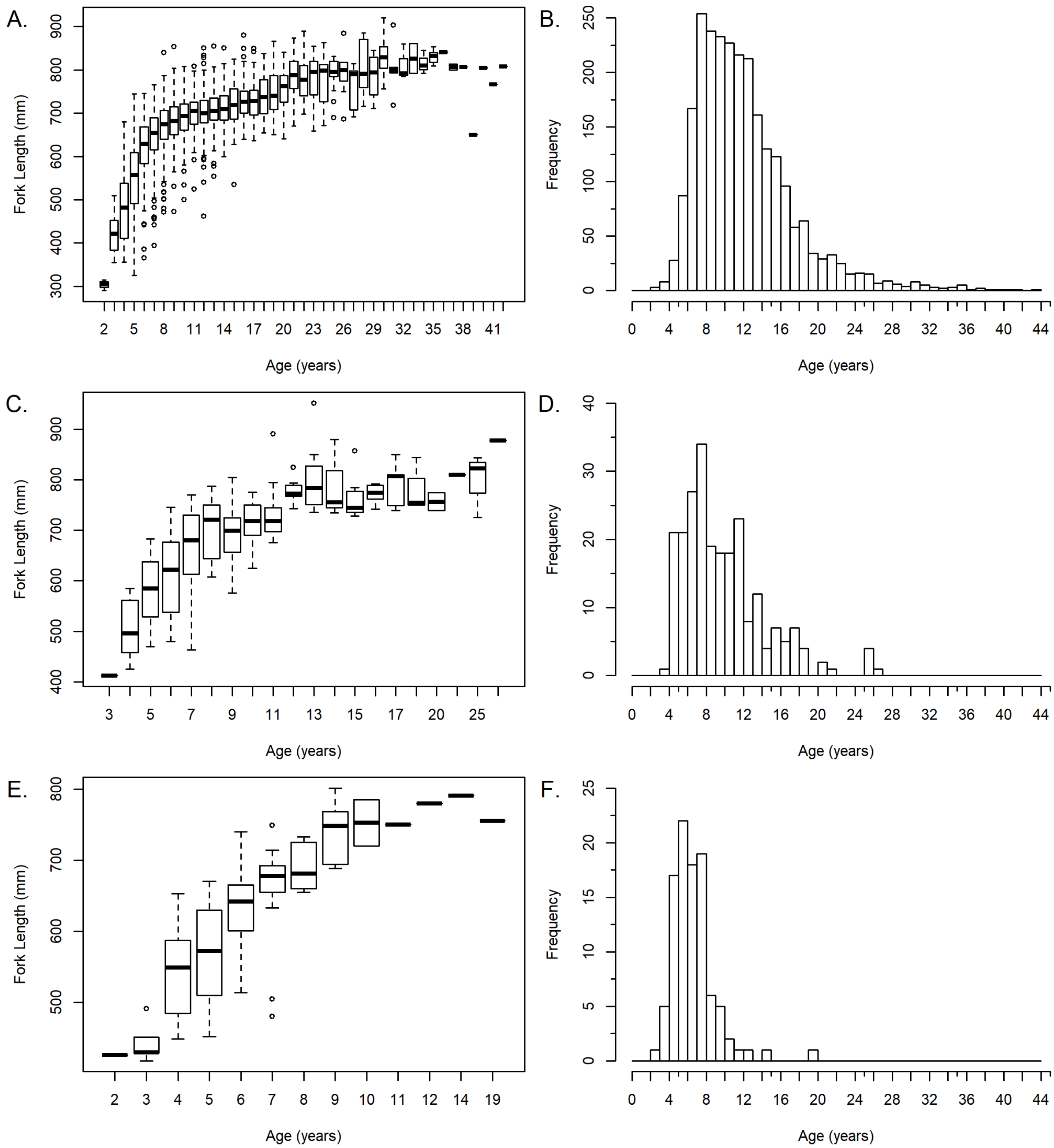


Figure 4. Length at age distribution and age distribution for red snapper captured during the SEFSC Bottom Longline Survey in the: **A.** and **B.** Western Gulf of Mexico, **C.** and **D.** Central Gulf of Mexico, and **E.** and **F.** Eastern Gulf of Mexico.

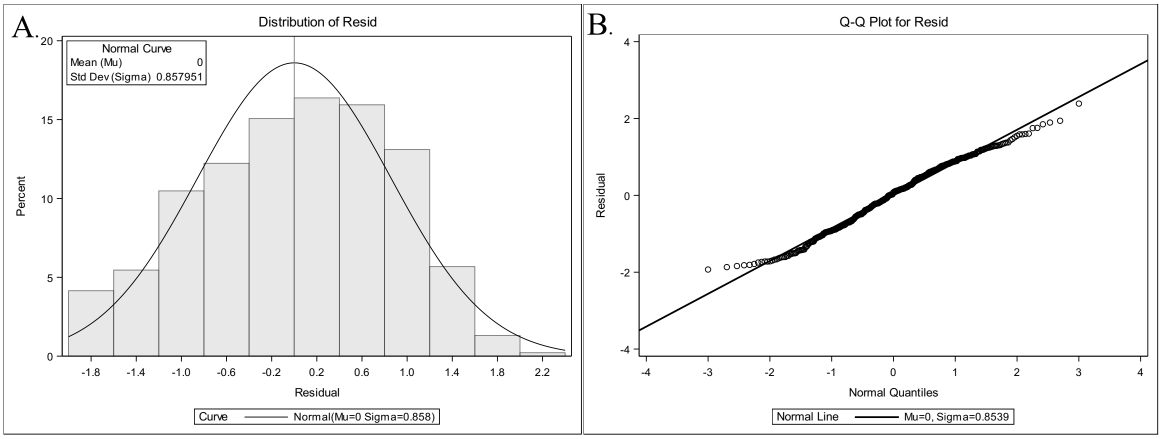


Figure 5. Diagnostic plots for lognormal component of the red snapper western Gulf of Mexico SEFSC Bottom Longline Surveys model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

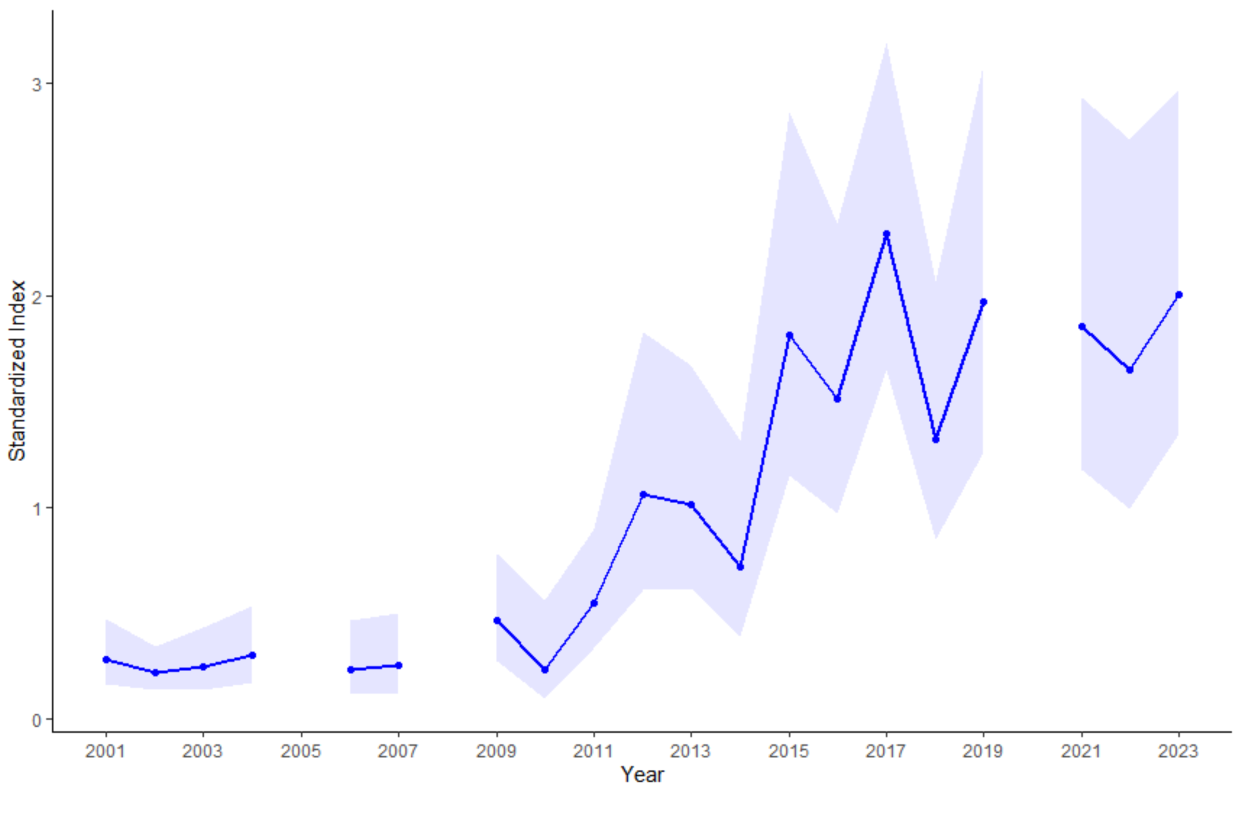


Figure 6. Annual index of abundance (blue line) and 95% confidence interval (shaded area) for the western Gulf of Mexico for red snapper from the SEFSC Bottom Longline Surveys from 2001 – 2023.

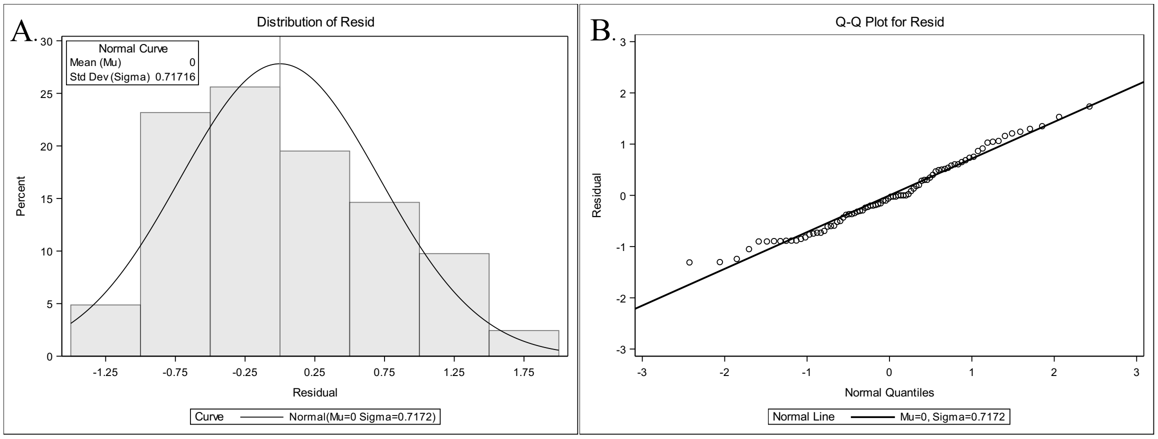


Figure 7. Diagnostic plots for lognormal component of the red snapper central Gulf of Mexico SEFSC Bottom Longline Surveys model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

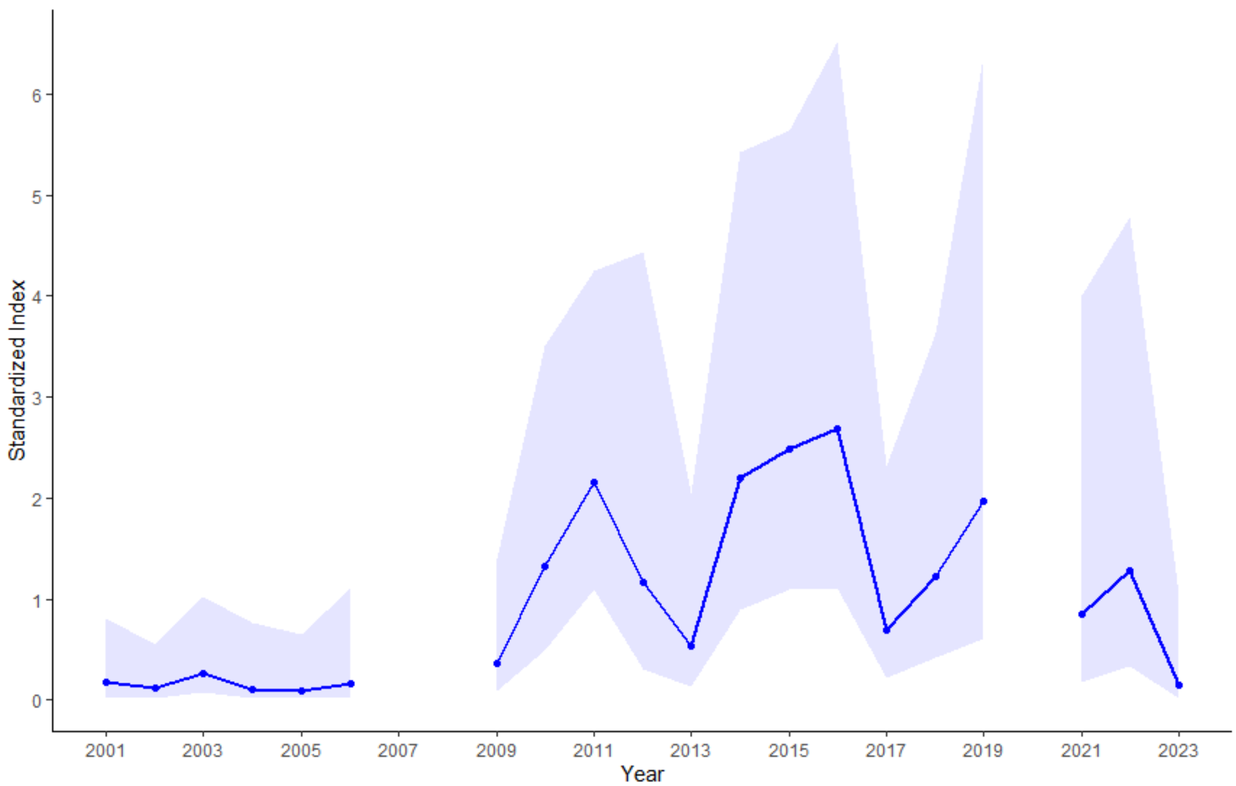


Figure 8. Annual index of abundance (blue line) and 95% confidence interval (shaded area) for the central Gulf of Mexico for red snapper from the SEFSC Bottom Longline Surveys from 2001 – 2023.

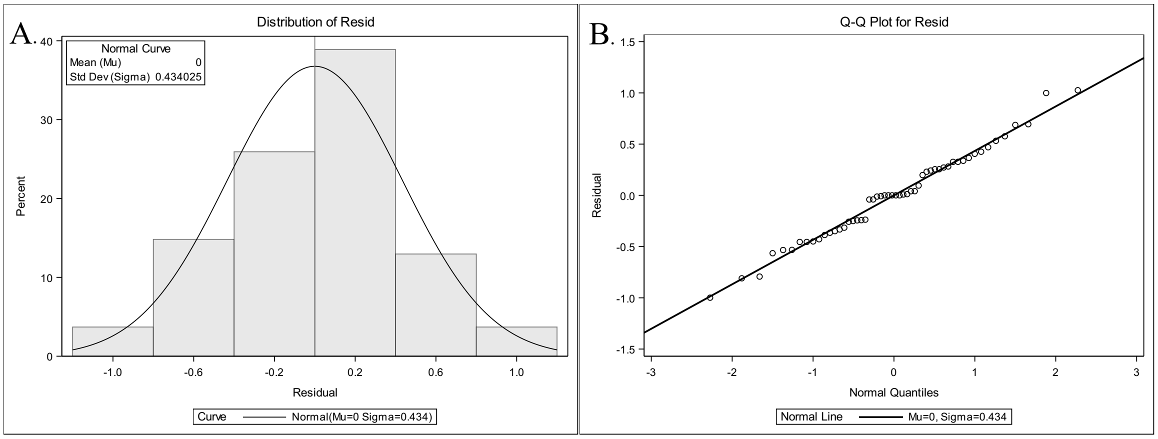


Figure 9. Diagnostic plots for lognormal component of the red snapper eastern Gulf of Mexico SEFSC Bottom Longline Surveys model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

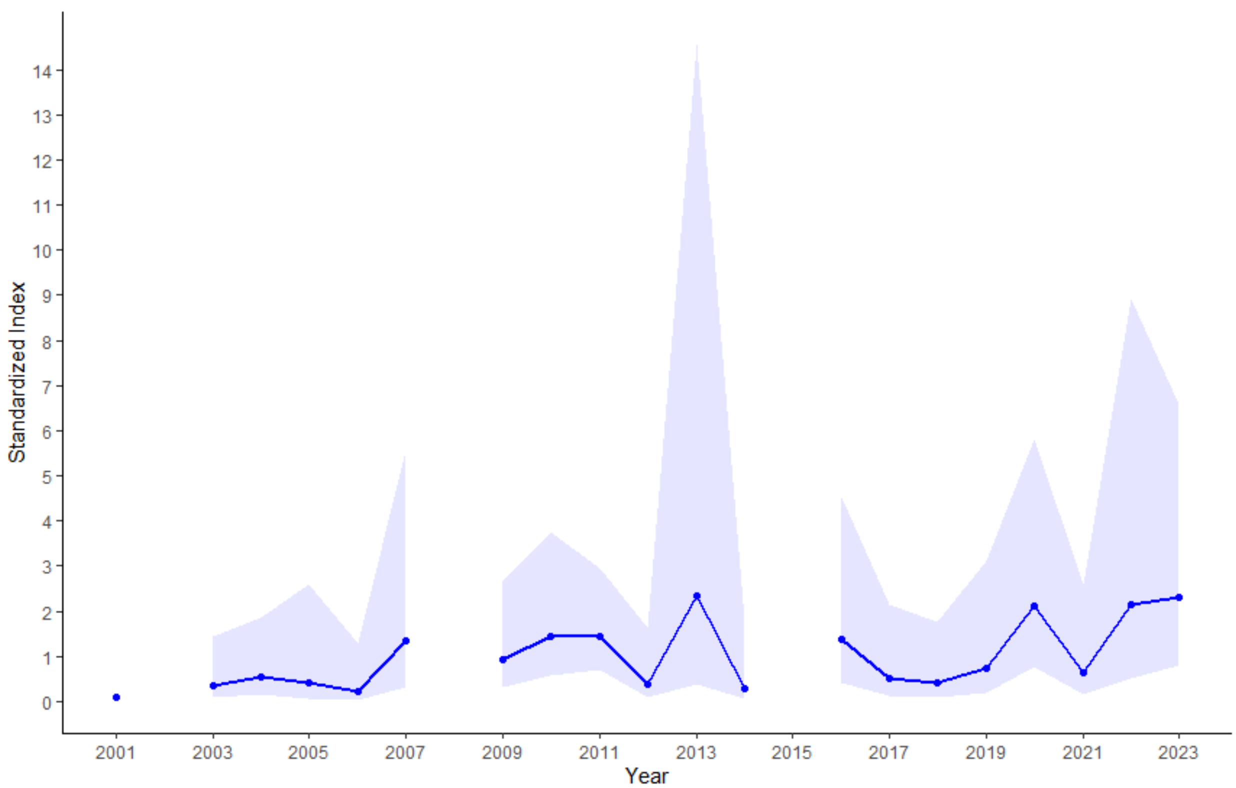


Figure 10. Annual index of abundance (blue line) and 95% confidence interval (shaded area) for the eastern Gulf of Mexico for red snapper from the eastern SEFSC Bottom Longline Surveys from 2001 – 2023.

Appendix

Appendix Table 1. Summary of the factors used in constructing the red snapper abundance index from the SEFSC Bottom Longline Survey data for the western Gulf of Mexico. Note the years 2005 and 2008 were excluded from the index and no data were collected in 2020.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2001	124	25	0.20161	0.66572
Year	2002	150	35	0.23333	0.49703
Year	2003	100	20	0.20000	0.61757
Year	2004	95	20	0.21053	0.67673
Year	2005				
Year	2006	71	13	0.18310	0.48715
Year	2007	70	13	0.18571	0.56404
Year	2008	21	6	0.28571	0.51147
Year	2009	76	23	0.30263	0.97119
Year	2010	46	8	0.17391	0.77463
Year	2011	80	25	0.31250	1.61792
Year	2012	53	19	0.35849	2.60952
Year	2013	62	22	0.35484	2.19276
Year	2014	47	15	0.31915	1.29886
Year	2015	56	25	0.44643	4.01264
Year	2016	54	27	0.50000	3.55434
Year	2017	67	42	0.62687	4.81354
Year	2018	59	27	0.45763	3.18762
Year	2019	48	24	0.50000	4.06618
Year	2020				
Year	2021	39	22	0.56410	4.35680
Year	2022	50	22	0.44000	3.83444
Year	2023	54	31	0.57407	4.75032
Zone	9	70	20	0.28571	1.57350
Zone	8	125	41	0.32800	2.34392
Zone	7	159	50	0.31447	1.70654
Zone	6	201	55	0.27363	1.44411
Zone	5	251	91	0.36255	1.74613
Zone	4	210	49	0.23333	1.29318
Zone	3	152	54	0.35526	2.43206
Zone	2	156	64	0.41026	2.75340
Zone	1	98	40	0.40816	2.13162

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Time of Day	Day	779	259	0.33248	1.70178
Time of Day	Night	643	205	0.31882	2.11043

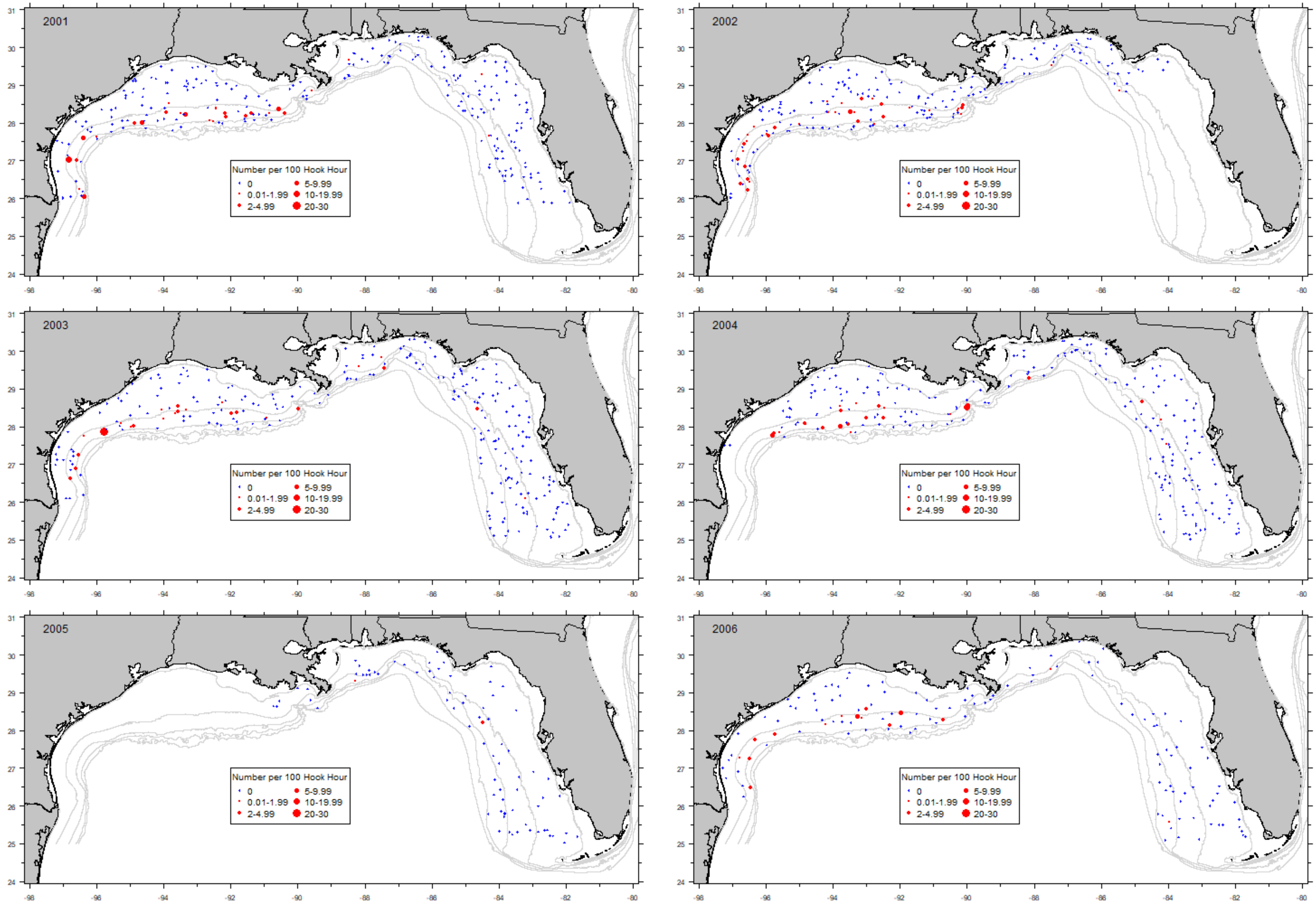
Appendix Table 2. Summary of the factors used in constructing the red snapper abundance index from the SEFSC Bottom Longline Survey data for the central Gulf of Mexico. Note the years 2007, 2008, and 2020 were excluded from the index.

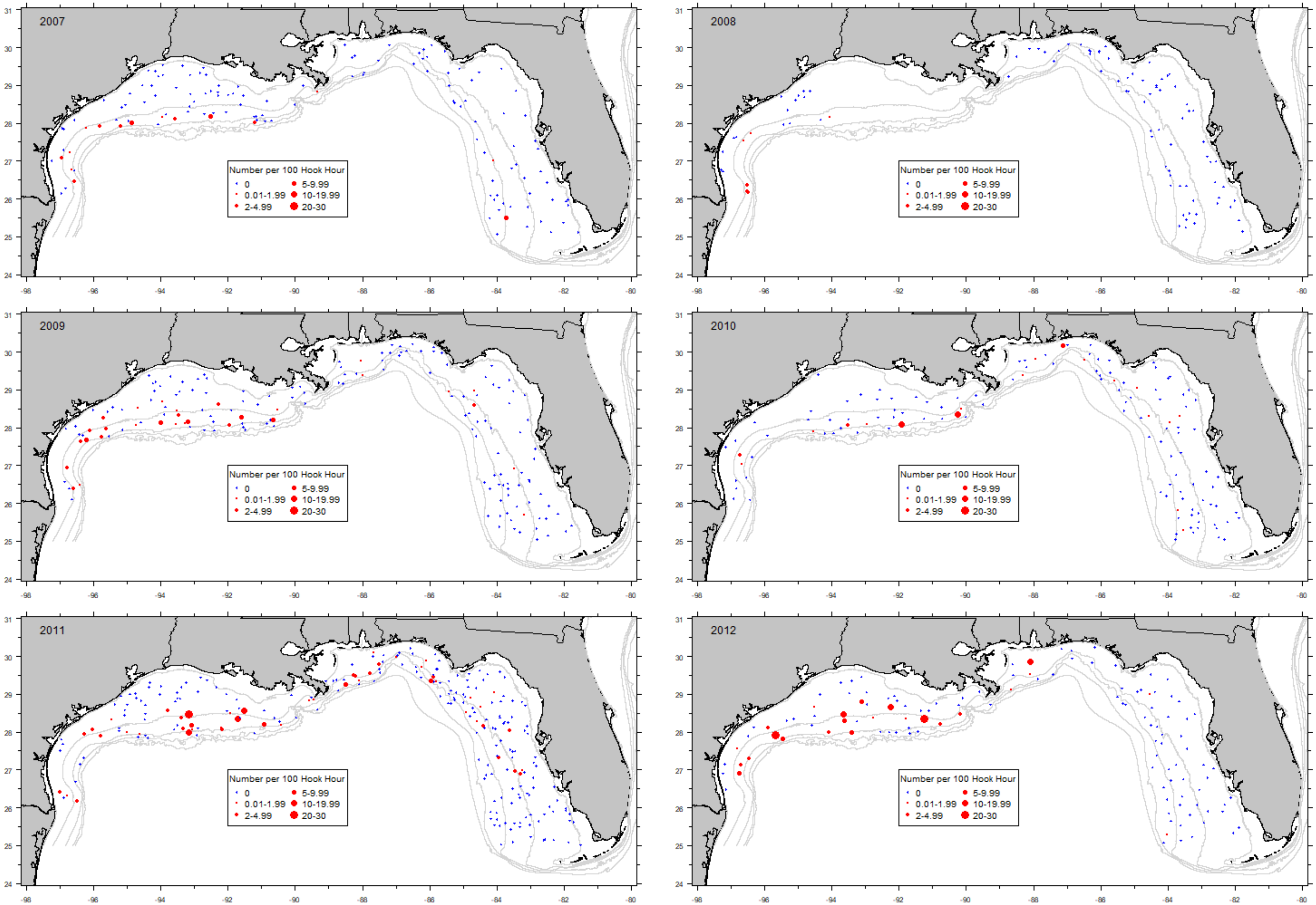
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2001	55	2	0.03636	0.05365
Year	2002	48	2	0.04167	0.04002
Year	2003	55	3	0.05455	0.08378
Year	2004	45	1	0.02222	0.04444
Year	2005	28	1	0.03571	0.03571
Year	2006	14	1	0.07143	0.07489
Year	2007				
Year	2008				
Year	2009	32	3	0.09375	0.12246
Year	2010	32	6	0.18750	0.34812
Year	2011	63	14	0.22222	0.60511
Year	2012	22	3	0.13636	0.70412
Year	2013	38	3	0.07895	0.27330
Year	2014	24	7	0.29167	0.54666
Year	2015	38	9	0.23684	0.73864
Year	2016	42	8	0.19048	1.17191
Year	2017	23	4	0.17391	0.21685
Year	2018	33	5	0.15152	0.42701
Year	2019	20	4	0.20000	0.75339
Year	2020				
Year	2021	24	2	0.08333	0.49904
Year	2022	30	3	0.10000	0.35976
Year	2023	21	1	0.04762	0.04909
Zone	14/15	108	4	0.03704	0.04578
Zone	13	174	12	0.06897	0.16591
Zone	12	145	10	0.06897	0.10355
Zone	11	122	20	0.16393	0.37831
Zone	10	138	36	0.26087	1.05767
Time of Day	Day	346	37	0.10694	0.30670
Time of Day	Night	341	45	0.13196	0.39537

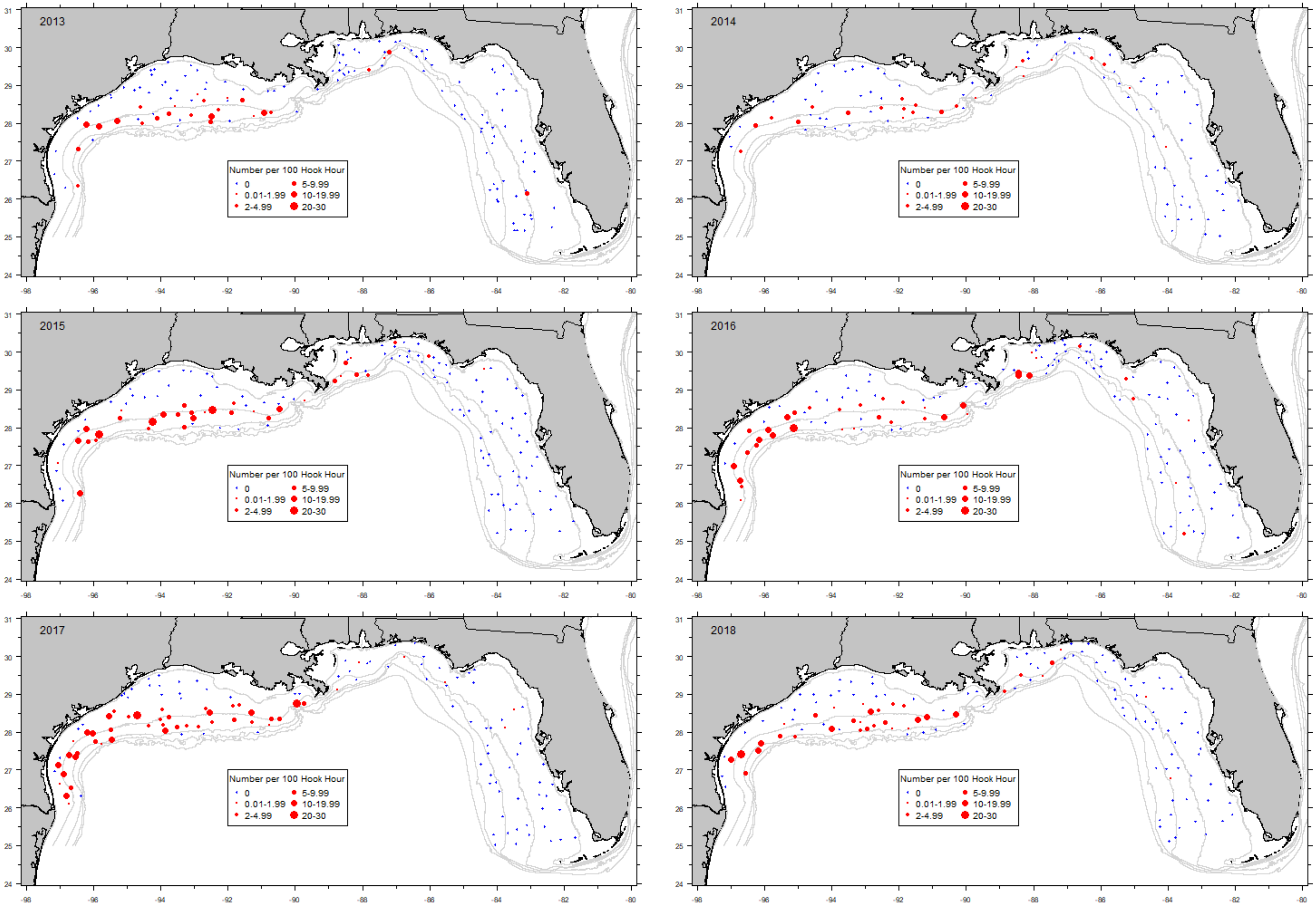
Appendix Table 3. Summary of the factors used in constructing the red snapper abundance index from the SEFSC Bottom Longline Survey data for the eastern Gulf of Mexico. Note the years 2002 and 2008 were excluded from the index.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Year	2001	67	1	0.01493	0.01468
Year	2002				
Year	2003	96	2	0.02083	0.04203
Year	2004	86	3	0.03488	0.05779
Year	2005	43	1	0.02326	0.04730
Year	2006	43	1	0.02326	0.02251
Year	2007	37	2	0.05405	0.19386
Year	2008				
Year	2009	53	4	0.07547	0.10519
Year	2010	48	5	0.10417	0.14307
Year	2011	95	10	0.10526	0.18167
Year	2012	45	2	0.04444	0.04343
Year	2013	37	1	0.02703	0.26852
Year	2014	31	1	0.03226	0.03226
Year	2015				
Year	2016	37	3	0.08108	0.15535
Year	2017	38	2	0.05263	0.05380
Year	2018	36	2	0.05556	0.05510
Year	2019	34	2	0.05882	0.08895
Year	2020	35	4	0.11429	0.17111
Year	2021	29	2	0.06897	0.06631
Year	2022	30	2	0.06667	0.25908
Year	2023	38	4	0.10526	0.32331
Zone	18	319	11	0.03448	0.06517
Zone	17	245	12	0.04898	0.12233
Zone	16	195	7	0.03590	0.06057
Zone	15	88	9	0.10227	0.17158
Zone	14	111	15	0.13514	0.23292
Time of Day	Day	519	26	0.05010	0.09196
Time of Day	Night	439	28	0.06378	0.12710

Appendix Figure 1. Annual survey effort and catch of red snapper from the SEFSC Bottom Longline Survey (2001-2023). 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
5-9.99
10-19.99
20-30


2013
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30
2014
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30
2015
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30
2016
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30
2017
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30
2018
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30
31
30
29
28
27
26
25
24
-98
-96
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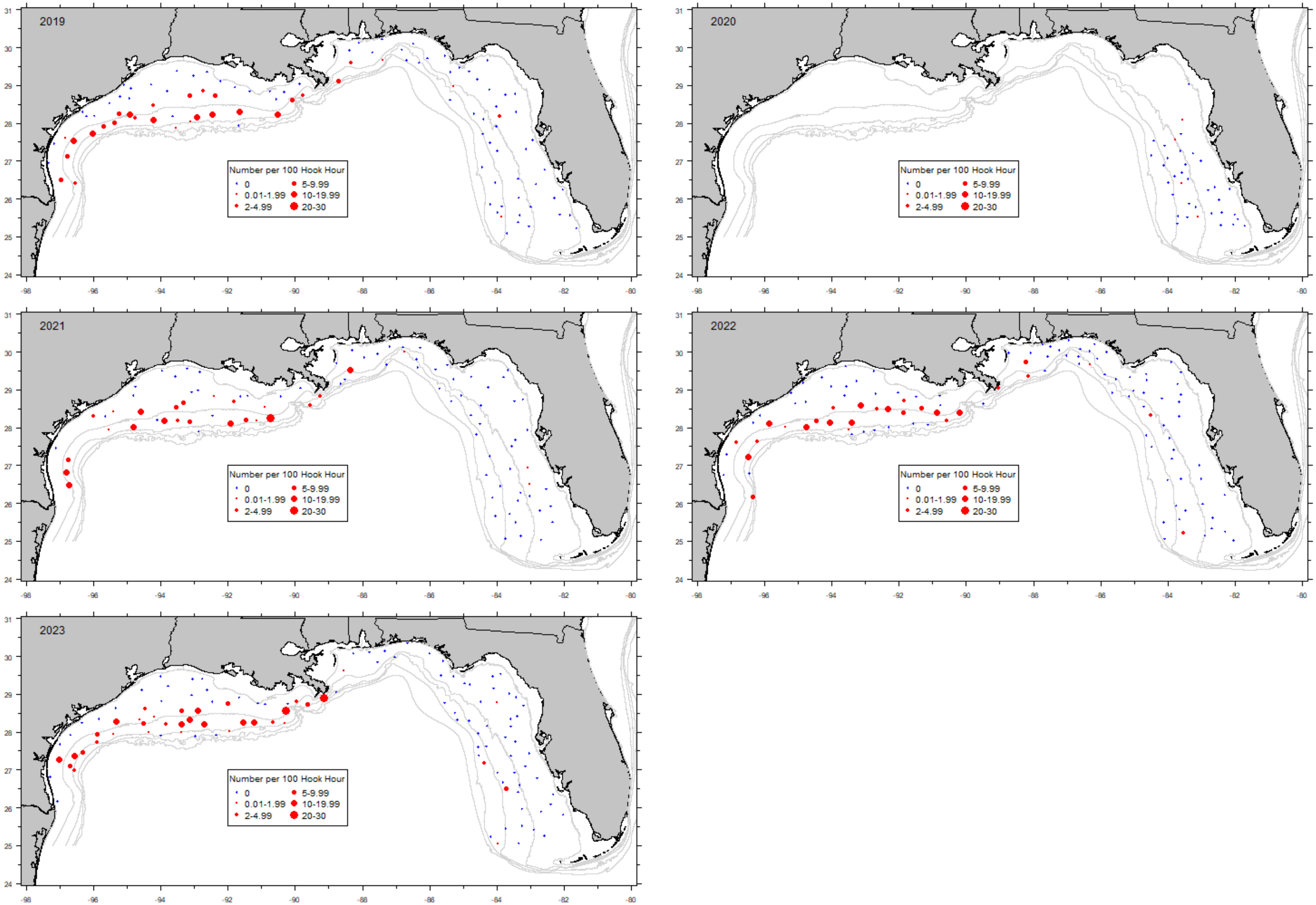
-86
-84
-82
-80


2019
2020
2021
2022
2023
Number per 100 Hook Hour
0
0.01-1.99
2-4.99
5-9.99
10-19.99
20-30