Red Snapper Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico

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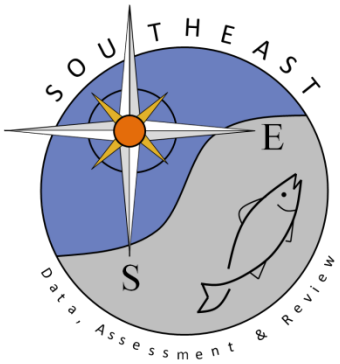

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Abstract

The NOAA Fisheries Service Southeast Fisheries Science Center Population and Ecosystem Monitoring Division Trawl and Plankton Branch and state partners have conducted groundfish surveys since 1972 in the northern Gulf of Mexico during the summer and fall under two different sampling programs. In 1987, both groundfish surveys (summer and fall) were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP). These fisheries independent datasets were used to develop abundance indices for red snapper (Lutjanus campechanus). Multiple abundance indices were developed with respect to changes in survey design and/or survey coverage and by season. The indices were split by season since the primary age class captured differs between the summer and fall surveys, age 0 and age 1, respectively.

Introduction

The NOAA Fisheries Southeast Fisheries Science Center (SEFSC) Population and Ecosystem Monitoring Division Trawl and Plankton Branch and state partners have conducted standardized fall groundfish surveys under the Southeast Area Monitoring and Assessment Program (SEAMAP) in the Gulf of Mexico (GOM) since 1987. Prior to 1987, the summer survey was conducted under SEAMAP protocols; however, the fall survey operated independent of SEAMAP and dates back to 1972. SEAMAP is a collaborative effort between federal, state and university programs, designed to collect, manage and distribute fishery independent data throughout the region. The primary objective of this trawl survey is to collect data on the abundance and distribution of demersal organisms in the northern GOM. This survey, which is conducted semi-annually (summer and fall), provides an important source of fisheries independent information on many commercially and recreationally important species throughout the GOM. The purpose of this document is to provide abundance indices for red snapper (*Lutjanus campechanus*).

Methodology

Survey Design

The survey methodologies and descriptions of the datasets used herein have been presented in detail by Nichols (2004) and Pollack and Ingram (2010). A change to the survey design was implemented between the summer and fall surveys of 2008. Prior to the fall survey of 2008, the basic structure of the groundfish surveys (i.e. 1987- summer of 2008) follows a stratified random station location assignment with strata derived from depth zones (5-6, 6-7, 7-8, 8-9, 9-10, 10-11, 11-12, 12-13, 13-14, 14-15, 15-16, 16-17, 17-18, 18-19, 19-20, 20-22, 22-25, 25-30, 30-35, 35-

40, 40-45, 45-50 and 50-60 fm), shrimp statistical zones (SSZ) (between 88° and 97° W longitude, paired SSZ from west to east: 21-20, 19-18, 17-16, 15-13 and 12-10), and time of day (i.e. day or night). Survey methodology prior to 1987 was presented in detail by Nichols (2004).

Starting in the fall of 2008 and continuing until the present, station allocation is randomized within each SSZ with a weighting by area. Other notable changes included a standardized 30 min tow and dropping the day/night stratification. The main purpose of these changes was to increase the sample size of each survey and expand the survey into the waters off of Florida.

Data

A total of 8,267 stations were sampled from 2008 - 2023 with 3,951 and 4,316 stations sampled during the summer and fall surveys, respectively (Tables 1 and 2). Trawl data from SEFSC was obtained from the SEFSC Oracle database and combined with data from the Gulf States Marine Fisheries Commission (GSMFC) database, which contains data collected by state agencies/partners from Alabama, Florida, Louisiana, Mississippi and Texas. Age data was obtained from the NOAA Fisheries SEFSC Panama City Laboratory. Finally, for this assessment, the GOM was broken down into three areas, western GOM (wGOM), central GOM (cGOM), and eastern GOM (eGOM) (Figure 1).

Data Exclusions

Data was limited to stations where no problems were reported (i.e. net torn, doors crossed, etc.) and were sampled with a 40 ft shrimp trawl (data from the state of Texas was not utilized because of the use of a 20 ft shrimp trawl).

Data Caveats

Data from the 1972 – 2008/2009 surveys was not updated in the document, but can be found in Pollack and Hanisko (2022).

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 III analyses with an inclusion level of significance of $\alpha = 0.05$. Binomial submodel performance was evaluated using Akaike Information Criterion (AIC), while the performance of the lognormal submodel was evaluated based on analyses of residual scatter and quantile-quantile (QQ) plots in addition to AIC. Variables that could be included in the submodels were:

Abundance Index – Western Gulf of Mexico – SEAMAP Fall Groundfish (new design)

Year: 2008 – 2023
Depth: 9 – 110 m (continuous variable)
SSZ: 13 – 21
Time of Day: Day and Night

Abundance Index – Central Gulf of Mexico –SEAMAP Fall Groundfish (new design)

Year: 2008 – 2023
Depth: 9 – 110 m (continuous variable)
SSZ: 7 – 11

Time of Day: Day and Night

Abundance Index – Eastern Gulf of Mexico –SEAMAP Fall Groundfish (new design)

Year: 2008 – 2023
Depth: 9 – 110 m (continuous variable)
SSZ: 2 – 6
Time of Day: Day and Night

Abundance Index – Western Gulf of Mexico – SEAMAP Summer Groundfish (new design)

Year: 2009 – 2019, 2021 – 2023
Depth: 9 – 110 m (continuous variable)
SSZ: 13 – 21
Time of Day: Day and Night

Abundance Index – Central Gulf of Mexico –SEAMAP Summer Groundfish (new design)

Year: 2009 – 2019, 2021 – 2023
Depth: 9 – 110 m (continuous variable)
SSZ: 7 – 11
Time of Day: Day and Night

Abundance Index – Eastern Gulf of Mexico –SEAMAP Summer Groundfish (new design)

Year: 2009 – 2019, 2021 – 2023
Depth: 9 – 110 m (continuous variable)
SSZ: 1 -6
Time of Day: Day and Night

DISL Data Incorporation

During previous assessments, a fishery-independent trawl survey conducted off the coast of Alabama by the Dauphin Island Sea Lab (DISL) was incorporated into the eastern Gulf of Mexico abundance indices at the request of the SEDAR31 Data Workshop Panel. However, since that time, the survey had been discontinued in 2021. Since the trawl data is no longer available, the decision was made no to combine the previous data in order to maintain a consistent time series across the central region.

Results and Discussion

Distribution, Size and Age

The distribution of red snapper is presented in Figure 2 with seasonal/annual abundance and distribution presented in the Appendix Figures 1 and 2. The length frequency distribution of red snapper used in the relative abundance index is shown in Figures 2 and 3 for the fall and summer surveys, respectively.

Abundance Index – Western Gulf of Mexico – SEAMAP Fall Groundfish (new design)

For the SEAMAP Fall Groundfish Survey (wGOM, 2008-2023) abundance index of red snapper, year, depth, and SSZ were retained in both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 3 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 11,022.6 and 5,063.6, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 5, and indicate the distribution of the residuals is normal. Annual abundance indices are presented in Table 4 and Figure 6.

Abundance Index – Central Gulf of Mexico –SEAMAP Fall Groundfish (new design)

For the SEAMAP Fall Groundfish Survey (cGOM, 2008-2023) abundance index of red snapper, year, depth, SSZ, and TOD were retained in the binomial submodel, while year, depth, and SSZ were retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 2. Table 5 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 3,686.4and 1,076.1, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 7, and indicate the distribution of the residuals is normal. Annual abundance indices are presented in Table 14 and Figure 8.

Abundance Index – Eastern Gulf of Mexico –SEAMAP Fall Groundfish (new design)

For the SEAMAP Fall Groundfish Survey (eGOM, 2008-2023) abundance index of red snapper, year, depth, and SSZ were retained in the binomial submodel, while year and SSZ were retained in the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 3. Table 15 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 5,472.0and 420.0, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 9, and indicate the distribution of the residuals is normal. Annual abundance indices are presented in Table 6 and Figure 10.

Abundance Index – Western Gulf of Mexico – SEAMAP Summer Groundfish (new design)

For the SEAMAP Summer Groundfish Survey (wGOM, 2009-2023) abundance index of red snapper, year, depth and SSZ were retained in both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 4. Table 7 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 10,258.1 and 3,436.6, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 11, and indicate the distribution of the residuals is normal. Annual abundance indices are presented in Table 8 and Figure 12.

Abundance Index – Central Gulf of Mexico –SEAMAP Summer Groundfish (new design)

For the SEAMAP Summer Groundfish Survey (eGOM, 2009-2023) abundance index of red snapper, year and SSZ were retained in both the binomial and lognormal submodels. A summary of the factors used in the analysis is presented in Appendix Table 5. Table 9 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 4,035.6 and 743.0, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 13, and indicate the distribution of the residuals is normal. Annual abundance indices are presented in Table 10 and Figure 14.

Abundance Index – Eastern Gulf of Mexico –SEAMAP Summer Groundfish (new design)

For the SEAMAP Summer Groundfish Survey (eGOM, 2009-2023) abundance index of red snapper, year and SSZ 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 6. Table 11 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 8,455.5 and 308.0, respectively. Diagnostic plots for the lognormal submodels are shown in Figure 15, and indicate the distribution of the residuals is normal. Annual abundance indices are presented in Table 12 and Figure 16.

DISL Data Incorporation

For the cGOM, two additional indices were built using a combination of SEAMAP and DISL data, that was similar to what had been used in previous assessments. Table 15 summarizes the backward selection process and the final set of variables used in the submodels and their significance for the summer survey, with the annual abundance index presented in Table 16 and Figure 17. Table 17 summarizes the backward selection process and the final set of variables used in the submodels and their significance for the summer survey, with the annual abundance index presented in Table 18 and Figure 17.

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Table 1. Number of stations sampled by shrimp statistical zone during the SEAMAP Summer Groundfish Surveys from 2009-2023.

	Shrimp Statistical Zone																				
Year	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
2009				36	23	29	15	16	18	24	67	25	20	36	39	46	50	33	29	23	529
2010			31	26	21	26	10	12	14	13	21	5	19	16	21	33	34	27	27	19	376
2011		11	24	22	20	29	2	15	11	8	16	7	14	17	23	29	29	18	21	13	329
2012		12	39	33	29	30	19	16	16	13	16	7	14	18	25	30	27	20	20	15	399
2013		9	27	28	23	19	8	11	9	7	14	5	12	14	22	21	22	16	17	12	296
2014		15	31	23	24	30	17	15	9	7	17	6	15	18	22	28	23	18	18	14	350
2015	1	9	32	29	22	27	22	18	10	8	16	7	15	18	21	28	27	19	20	13	362
2016		9	25	29	26	22	15	15	10	8	16	6	16	16	21	30	23	19	17	14	337
2017		10	28	19	28	14	15	14	6	10	17	7	14	13	23	26	24	19	21	14	322
2018		8	30	28	24	23	16	12	5	7	14	7	12	14	21	26	19	11	11	14	302
2019		11	31	23	21	15	5	15	8	9	14	3	12	13	20	27	22	16	20	12	297
2020																					
2021		9	24	21	19	3		9	7	6	6	4	9	8	17	22	20	14	14	11	223
2022		6	23	21	20	24	2	11	9	6	11	5	17	15	18	20	21	15	15	9	268
2023		8	26	28	24	17	8	9	7	6	15	5	12	12	19	27	23	19	17	11	293

Table 2. Number of stations sampled by shrimp statistical zone during the SEAMAP Fall Groundfish Surveys from 2008-2023.

	Shrimp Statistical Zone																				
Year	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
2008					15	14	4	4	3	4	35	17	28	34	42	46	44	19	36	20	365
2009				20	21	25	11	21	13	12	50	12	23	23	30	49	47	31	36	22	446
2010				9	25	27	17	16	11	14	15	7	15	18	26	30	29	18	19	14	310
2011								9	11	7	15	6	15	16	27	31	28	21	18	15	219
2012			2	3	6	6	17	10	7	5	12	5	11	13	19	23	22	13	15	11	200
2013		4	14	10	10	11	10	10	6	5	10	5	11	9	3	12	16	12	14	9	181
2014	1	8	31	25	22	23	13	12	7	7	16	5	13	14	21	27	22	15	17	12	311
2015	1	10	28	25	25	21	14	12	9	11	16	6	13	13	19	27	21	16	17	12	316
2016	1	5	4	8	11	9	6	13	5	4	8	4	12	11	18	22	17	13	13	8	192
2017		9	19	27	19	18	8	12	7	7	15	6	9	12	22	25	22	15	18	14	284
2018		9	29	21	14	10	7	13	8	7	13	5	12	15	21	25	22	13	15	14	273
2019		11	17	17	19	24	9	11	9	10	12	4	9	13	20	25	22	16	16	12	276
2020		9	15	17	20	8	4	8	7	9	12	4	9	10	18	22	18	15	14	11	230
2021		6	23	17	17	14	2	12	5	6	12	4	11	12	19	25	22	16	16	12	251
2022		6	22	20	14	16	9	10	7	6	10	2	10		2	11	11	16	16	12	200
2023		8	26	25	21	17	9	7	2	6	12	6	13	11	15	25	22	13	15	9	262

Table 3. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP Fall Groundfish Survey (wGOM, 2008-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 11025.4)*						*Lognormal Submodel Type 3 Tests (AIC 5065.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	15	2406	54.69	3.65	<.0001	<.0001	15	1585	9.11	<.0001
Depth	1	2406	5.59	5.59	0.0181	0.0181	1	1585	26.47	<.0001
Statistical Zone	8	2406	186.00	23.25	<.0001	<.0001	8	1585	44.89	<.0001
Time of Day	1	2406	0.01	0.01	0.9236	0.9236	1	1585	2.42	0.1200
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 11022.6)*						*Lognormal Submodel Type 3 Tests (AIC 5063.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	15	2407	54.75	3.65	<.0001	<.0001	15	1586	9.04	<.0001
Depth	1	2407	5.60	5.60	0.0179	0.0180	1	1586	26.28	<.0001
Statistical Zone	8	2407	186.09	23.26	<.0001	<.0001	8	1586	44.72	<.0001
Time of Day				Dropped					Dropped	

Table 4. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP Fall Groundfish Survey (wGOM, 2008-2023). 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
2008	0.61888	286	9.8248	0.47272	0.10080	0.38661	0.57801
2009	0.73260	273	33.2193	1.59835	0.09207	1.33006	1.92075
2010	0.59659	176	15.5796	0.74961	0.13057	0.57797	0.97223
2011	0.64972	177	18.1531	0.87343	0.12282	0.68383	1.11562
2012	0.78030	132	35.2738	1.69720	0.12308	1.32809	2.16890
2013	0.61538	91	14.7877	0.71151	0.18201	0.49588	1.02091
2014	0.69863	146	20.3138	0.97740	0.12776	0.75780	1.26064
2015	0.78472	144	37.1102	1.78556	0.11746	1.41286	2.25657
2016	0.62712	118	24.7236	1.18958	0.15221	0.87890	1.61007
2017	0.58741	143	17.1311	0.82426	0.14685	0.61545	1.10391
2018	0.71831	142	24.0186	1.15566	0.12640	0.89840	1.48657
2019	0.59854	137	18.6698	0.89830	0.14795	0.66928	1.20567
2020	0.54545	121	9.5920	0.46152	0.16814	0.33050	0.64449
2021	0.65693	137	18.8471	0.90683	0.13807	0.68891	1.19368
2022	0.80000	80	20.3684	0.98003	0.16192	0.71041	1.35198
2023	0.60465	129	14.9236	0.71805	0.15064	0.53216	0.96887

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP Fall Groundfish Survey (cGOM, 2008-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 3686.4)*						*Lognormal Submodel Type 3 Tests (AIC 1077.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	15	798	12.62	0.84	0.6313	0.6311	15	326	2.38	0.0029
Depth	1	798	11.61	11.61	0.0007	0.0007	1	326	4.45	0.0356
Statistical Zone	4	798	103.94	25.99	<.0001	<.0001	4	326	9.77	<.0001
Time of Day	1	798	4.16	4.16	0.0415	0.0418	1	326	0.98	0.3230
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 3686.4)*						*Lognormal Submodel Type 3 Tests (AIC 1076.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	15	798	12.62	0.84	0.6313	0.6311	15	327	2.35	0.0033
Depth	1	798	11.61	11.61	0.0007	0.0007	1	327	4.39	0.0368
Statistical Zone	4	798	103.94	25.99	<.0001	<.0001	4	327	9.91	<.0001
Time of Day	1	798	4.16	4.16	0.0415	0.0418	Dropped			

Table 6. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP Fall Groundfish Survey (cGOM, 2008-2023). 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
2008	0.46000	50	3.3462	0.60506	0.33924	0.31270	1.17077
2009	0.58879	107	12.9956	2.34988	0.19049	1.61087	3.42791
2010	0.31507	73	3.6326	0.65684	0.30568	0.36129	1.19416
2011	0.42857	42	3.5248	0.63736	0.34401	0.32651	1.24415
2012	0.45098	51	7.4128	1.34038	0.29332	0.75456	2.38103
2013	0.31707	41	3.8291	0.69239	0.40033	0.32024	1.49703
2014	0.43636	55	5.3859	0.97389	0.29582	0.54568	1.73813
2015	0.43548	62	6.9631	1.25908	0.27923	0.72787	2.17796
2016	0.33333	36	5.4893	0.99257	0.41543	0.44687	2.20465
2017	0.36735	49	2.7374	0.49498	0.34958	0.25099	0.97616
2018	0.41667	48	7.7596	1.40310	0.32026	0.75106	2.62123
2019	0.37255	51	3.7664	0.68105	0.32934	0.35847	1.29392
2020	0.40000	40	3.0231	0.54663	0.36408	0.26993	1.10698
2021	0.35135	37	3.5776	0.64691	0.41103	0.29354	1.42568
2022	0.42857	42	5.2111	0.94228	0.33158	0.49391	1.79768
2023	0.50000	36	9.8306	1.77758	0.33243	0.93029	3.39657

Table 7. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP Fall Groundfish Survey (eGOM, 2008-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 5488.1)*						*Lognormal Submodel Type 3 Tests (AIC 429.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	14	1040	28.47	2.03	0.0123	0.0132	14	133	2.91	0.0007
Depth	1	1040	18.70	18.70	<.0001	<.0001	1	133	0.02	0.8754
Statistical Zone	4	1040	24.28	6.07	<.0001	<.0001	4	133	4.52	0.0019
Time of Day	1	1040	2.21	2.21	0.1373	0.1376	1	133	0.34	0.5636
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 5472.0)*						*Lognormal Submodel Type 3 Tests (AIC 421.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	14	1041	29.51	2.11	0.0089	0.0096	14	134	2.96	0.0006
Depth	1	1041	19.00	19.00	<.0001	<.0001		Dropped		
Statistical Zone	4	1041	23.63	5.91	<.0001	0.0001	4	134	4.98	0.0009
Time of Day				Dropped			1	134	0.38	0.5404
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 5472.0)*						*Lognormal Submodel Type 3 Tests (AIC 420.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	14	1041	29.51	2.11	0.0089	0.0096	14	135	3.03	0.0004
Depth	1	1041	19.00	19.00	<.0001	<.0001		Dropped		
Statistical Zone	4	1041	23.63	5.91	<.0001	0.0001	4	135	4.94	0.0010
Time of Day				Dropped				Dropped		

Table 8. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP Fall Groundfish Survey (eGOM, 2008-2023). 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
2008	0.10345	29	0.80544	0.65799	0.78389	0.16484	2.62648
2009	0.10606	66	0.41043	0.33529	0.52567	0.12485	0.90044
2010	0.18033	61	0.81303	0.66418	0.42289	0.29510	1.49488
2011							
2012	0.17647	17	1.05947	0.86551	0.76815	0.22170	3.37896
2013	0.06122	49	0.17984	0.14692	0.77396	0.03732	0.57831
2014	0.14679	109	3.46401	2.82983	0.34470	1.44784	5.53095
2015	0.19266	109	1.27130	1.03856	0.29778	0.57976	1.86041
2016	0.27027	37	1.53391	1.25309	0.42123	0.55840	2.81204
2017	0.16304	92	0.82478	0.67378	0.35757	0.33669	1.34836
2018	0.07229	83	0.33638	0.27480	0.55476	0.09752	0.77435
2019	0.13636	88	0.80355	0.65644	0.39618	0.30587	1.40880
2020	0.05797	69	0.31244	0.25524	0.67806	0.07460	0.87332
2021	0.24675	77	4.35071	3.55420	0.30786	1.94702	6.48804
2022	0.17949	78	1.62244	1.32541	0.35627	0.66389	2.64610
2023	0.10309	97	0.57381	0.46876	0.43560	0.20366	1.07895

Table 9. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP Summer Groundfish Survey (wGOM, 2009-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 10264.3)*						*Lognormal Submodel Type 3 Tests (AIC 3439.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	2298	90.37	6.95	<.0001	<.0001	13	1096	6.71	<.0001
Depth	1	2298	16.49	16.49	<.0001	<.0001	1	1096	6.93	0.0086
Statistical Zone	8	2298	226.66	28.33	<.0001	<.0001	8	1096	7.90	<.0001
Time of Day	1	2298	2.45	2.45	0.1172	0.1174	1	1096	0.72	0.3947
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 10258.1)*						*Lognormal Submodel Type 3 Tests (AIC 3436.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	2299	89.73	6.90	<.0001	<.0001	13	1097	6.70	<.0001
Depth	1	2299	16.51	16.51	<.0001	<.0001	1	1097	7.03	0.0081
Statistical Zone	8	2299	226.33	28.29	<.0001	<.0001	8	1097	7.83	<.0001
Time of Day				Dropped					Dropped	

Table 10. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP Summer Groundfish Survey (wGOM, 2009-2023). 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
2009	0.29568	301	2.3577	0.30077	0.15563	0.22073	0.40982
2010	0.44776	201	5.6944	0.72641	0.15162	0.53732	0.98205
2011	0.49708	171	7.7749	0.99182	0.15024	0.73563	1.33723
2012	0.52273	176	5.5150	0.70352	0.14364	0.52863	0.93628
2013	0.48227	141	8.4316	1.07559	0.16895	0.76900	1.50441
2014	0.44444	162	5.1251	0.65379	0.16488	0.47118	0.90718
2015	0.49405	168	7.1619	0.91362	0.15239	0.67478	1.23701
2016	0.50000	162	5.8322	0.74399	0.15332	0.54849	1.00918
2017	0.45963	161	5.6091	0.71554	0.16364	0.51693	0.99045
2018	0.62222	135	10.9804	1.40074	0.14160	1.05676	1.85669
2019	0.52414	145	7.4739	0.95341	0.15827	0.69608	1.30588
2020							
2021	0.42017	119	4.7399	0.60466	0.20135	0.40583	0.90088
2022	0.58519	135	12.8716	1.64198	0.14827	1.22260	2.20524
2023	0.66897	145	20.1790	2.57417	0.13172	1.98023	3.34624

Table 11. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP Summer Groundfish Survey (cGOM, 2009-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 4049.5)*						*Lognormal Submodel Type 3 Tests (AIC 751.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	854	27.50	2.12	0.0106	0.0115	13	229	0.62	0.8363
Depth	1	854	0.00	0.00	0.9655	0.9655	1	229	1.01	0.3163
Statistical Zone	4	854	71.09	17.77	<.0001	<.0001	4	229	5.02	0.0007
Time of Day	1	854	3.15	3.15	0.0758	0.0762	1	229	1.37	0.2425
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 4040.6)*						*Lognormal Submodel Type 3 Tests (AIC 743.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	855	27.76	2.14	0.0098	0.0106	13	230	0.62	0.8388
Depth				Dropped				Dropped		
Statistical Zone	4	855	71.17	17.79	<.0001	<.0001	4	230	4.93	0.0008
Time of Day	1	855	3.16	3.16	0.0756	0.0759	1	230	1.34	0.2482
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 4035.6)*						*Lognormal Submodel Type 3 Tests (AIC 743.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	856	26.64	2.05	0.0139	0.0150	13	231	0.61	0.8489
Depth				Dropped				Dropped		
Statistical Zone	4	856	70.33	17.58	<.0001	<.0001	4	231	4.67	0.0012
Time of Day				Dropped				Dropped		

Table 12. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP Summer Groundfish Survey (cGOM, 2009-2023). 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
2009	0.23571	140	1.08808	0.46672	0.27112	0.27398	0.79503
2010	0.29577	71	2.44433	1.04846	0.31742	0.56420	1.94838
2011	0.23077	52	1.30206	0.55850	0.42170	0.24867	1.25436
2012	0.26250	80	2.56160	1.09876	0.31375	0.59533	2.02793
2013	0.28571	49	3.14645	1.34962	0.38274	0.64426	2.82726
2014	0.21538	65	1.25601	0.53875	0.38859	0.25448	1.14056
2015	0.20270	74	2.04927	0.87901	0.37398	0.42631	1.81241
2016	0.31250	64	2.50722	1.07544	0.31857	0.57748	2.00279
2017	0.48387	62	3.87920	1.66393	0.24855	1.01969	2.71518
2018	0.33333	54	3.38726	1.45292	0.33279	0.75987	2.77806
2019	0.27451	51	1.79224	0.76875	0.38666	0.36439	1.62185
2020							
2021	0.28571	28	1.57789	0.67681	0.49714	0.26440	1.73248
2022	0.30769	39	2.19768	0.94266	0.41102	0.42774	2.07745
2023	0.37778	45	3.44962	1.47967	0.34373	0.75841	2.88687

Table 13. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP Summer Groundfish Survey (eGOM, 2009-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 8475.5)*						*Lognormal Submodel Type 3 Tests (AIC 315.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	1466	35.48	2.73	0.0007	0.0008	13	108	2.44	0.0062
Depth	1	1466	0.82	0.82	0.3659	0.3661	1	108	1.77	0.1858
Statistical Zone	4	1466	15.51	3.88	0.0037	0.0039	4	108	1.11	0.3564
Time of Day	1	1466	0.57	0.57	0.4492	0.4494	1	108	2.44	0.1213
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 8475.7)*						*Lognormal Submodel Type 3 Tests (AIC 314.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	1467	35.43	2.73	0.0007	0.0008	13	112	2.28	0.0106
Depth	1	1467	0.75	0.75	0.3859	0.3860	1	112	1.48	0.2269
Statistical Zone	4	1467	15.27	3.82	0.0042	0.0043		Dropped		
Time of Day				Dropped			1	112	1.80	0.1822
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 8455.5)*						*Lognormal Submodel Type 3 Tests (AIC 308.1)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	1468	35.11	2.70	0.0008	0.0009	13	113	2.77	0.0019
Depth				Dropped				Dropped		
Statistical Zone	4	1468	15.72	3.93	0.0034	0.0035		Dropped		
Time of Day				Dropped			1	113	1.90	0.1705
Model Run #4	*Binomial Submodel Type 3 Tests (AIC 8455.5)*						*Lognormal Submodel Type 3 Tests (AIC 308.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	1468	35.11	2.70	0.0008	0.0009	13	114	2.68	0.0025
Depth				Dropped				Dropped		
Statistical Zone	4	1468	15.72	3.93	0.0034	0.0035		Dropped		
Time of Day				Dropped				Dropped		

Table 14. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP Summer Groundfish Survey (eGOM, 2009-2023). 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
2009	0.02273	88	0.05421	0.10936	0.89048	0.02372	0.50416
2010	0.00962	104	0.02082	0.04201	1.22713	0.00618	0.28567
2011	0.06604	106	0.56913	1.14828	0.48129	0.46087	2.86096
2012	0.06294	143	0.28628	0.57759	0.42456	0.25587	1.30381
2013	0.01887	106	0.08147	0.16436	0.88700	0.03582	0.75429
2014	0.07317	123	0.19226	0.38791	0.42464	0.17182	0.87577
2015	0.12605	119	1.69180	3.41335	0.32509	1.81081	6.43411
2016	0.18018	111	1.02233	2.06264	0.27690	1.19768	3.55227
2017	0.13131	99	0.74798	1.50911	0.34612	0.77011	2.95728
2018	0.13274	113	0.60292	1.21644	0.32356	0.64716	2.28648
2019	0.05941	101	0.26411	0.53286	0.51652	0.20147	1.40931
2020							
2021	0.11842	76	0.42563	0.85875	0.41373	0.38779	1.90165
2022	0.09574	94	0.52665	1.06256	0.42151	0.47326	2.38567
2023	0.10680	103	0.45341	0.91479	0.37841	0.44012	1.90137

Table 15. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP/DISL Fall Groundfish Survey (cGOM, 2008-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 4067.3)*						*Lognormal Submodel Type 3 Tests (AIC 1198.8)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	15	881	15.69	1.05	0.4032	0.4048	15	364	2.06	0.0113
Depth	1	881	14.98	14.98	0.0001	0.0001	1	364	6.96	0.0087
Statistical Zone	4	881	116.70	29.18	<.0001	<.0001	4	364	11.64	<.0001
Time of Day	1	881	4.18	4.18	0.0408	0.0411	1	364	1.97	0.1611
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 4067.3)*						*Lognormal Submodel Type 3 Tests (AIC 1198.3)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	15	881	15.69	1.05	0.4032	0.4048	15	365	1.96	0.0174
Depth	1	881	14.98	14.98	0.0001	0.0001	1	365	7.59	0.0062
Statistical Zone	4	881	116.70	29.18	<.0001	<.0001	4	365	11.83	<.0001
Time of Day	1	881	4.18	4.18	0.0408	0.0411	Dropped			

Table 16. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP/DISL Fall Groundfish Survey (cGOM, 2008-2023). 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
2008	0.46000	50	3.4252	0.58586	0.34139	0.30158	1.13813
2009	0.58879	107	13.2538	2.26700	0.18988	1.55589	3.30311
2010	0.31765	85	4.1683	0.71297	0.28181	0.41017	1.23932
2011	0.42857	42	3.6615	0.62628	0.34497	0.32027	1.22467
2012	0.45098	51	7.7225	1.32090	0.29366	0.74312	2.34792
2013	0.33333	57	4.2643	0.72938	0.33505	0.37987	1.40047
2014	0.43636	55	5.5836	0.95506	0.29649	0.53445	1.70668
2015	0.43548	62	7.3143	1.25109	0.27954	0.72282	2.16543
2016	0.33333	36	5.8038	0.99272	0.41680	0.44586	2.21032
2017	0.39474	76	3.3412	0.57150	0.27930	0.33034	0.98872
2018	0.48214	56	7.7648	1.32814	0.27315	0.77669	2.27111
2019	0.37255	51	3.9572	0.67686	0.32984	0.35593	1.28717
2020	0.44643	56	4.2444	0.72599	0.30613	0.39899	1.32100
2021	0.31707	41	3.2798	0.56099	0.41369	0.25335	1.24219
2022	0.42857	42	5.4573	0.93345	0.33203	0.48888	1.78232
2023	0.50000	36	10.3002	1.76181	0.33283	0.92134	3.36896

Table 17. Summary of backward selection procedure for building delta-lognormal submodels for red snapper SEAMAP/DISL Summer Groundfish Survey (cGOM, 2009-2023) index of relative abundance.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 4870.8)*						*Lognormal Submodel Type 3 Tests (AIC 900.5)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	1028	28.94	2.23	0.0067	0.0072	13	276	0.88	0.5766
Depth	13	1028	28.94	2.23	0.0067	0.0072	13	276	0.88	0.5766
Statistical Zone	4	1028	95.40	23.85	<.0001	<.0001	4	276	7.43	<.0001
Time of Day	1	1028	4.04	4.04	0.0445	0.0448	1	276	0.58	0.4481
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 4861.4)*						*Lognormal Submodel Type 3 Tests (AIC 899.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	1029	29.13	2.24	0.0063	0.0068	13	277	0.87	0.5821
Depth				Dropped			1	277	4.69	0.0313
Statistical Zone	4	1029	95.52	23.88	<.0001	<.0001	4	277	7.30	<.0001
Time of Day	1	1029	4.14	4.14	0.0418	0.0421		Dropped		

Table 18. Index of red snapper abundance developed using the delta-lognormal (DL) model for SEAMAP/DISL Summer Groundfish Survey (cGOM, 2009-2023). 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
2009	0.23571	140	1.10630	0.43521	0.27183	0.25515	0.74235
2010	0.29577	71	2.57414	1.01265	0.31737	0.54498	1.88165
2011	0.23438	64	1.45134	0.57095	0.37844	0.27468	1.18677
2012	0.26250	80	3.00907	1.18375	0.31514	0.63971	2.19046
2013	0.25373	67	3.41074	1.34176	0.35020	0.67959	2.64911
2014	0.24176	91	1.66062	0.65328	0.31689	0.35189	1.21280
2015	0.17822	101	1.62936	0.64098	0.34868	0.32556	1.26200
2016	0.28395	81	2.43699	0.95870	0.29941	0.53356	1.72258
2017	0.45455	88	4.26291	1.67700	0.22343	1.07851	2.60761
2018	0.31818	66	2.89887	1.14040	0.31322	0.61850	2.10268
2019	0.32051	78	3.58415	1.40998	0.29387	0.79291	2.50726
2020							
2021	0.29730	37	1.48259	0.58324	0.43212	0.25495	1.33424
2022	0.30769	39	2.37866	0.93575	0.41483	0.42175	2.07620
2023	0.37778	45	3.70207	1.45637	0.34716	0.74177	2.85941

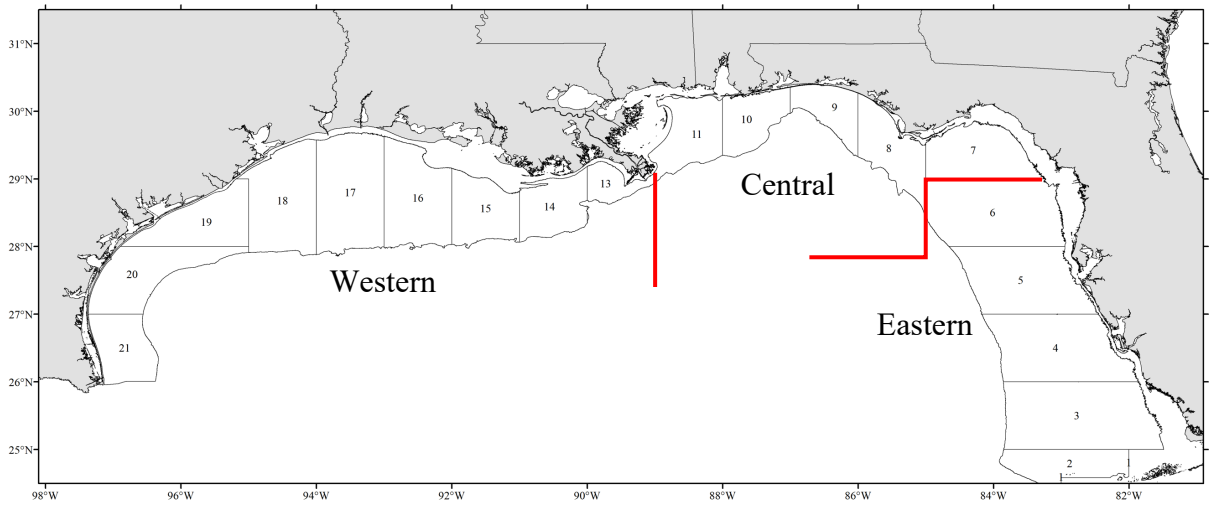


Figure 1. Breakdown of Gulf of Mexico for the SEAMAP Groundfish Survey by shrimp statistical zone. Red lines represent the boundaries for the three areas for which indices were produced according to the SEDAR 74 Stock ID Workshop (SEDAR 74 Stock ID 2021).

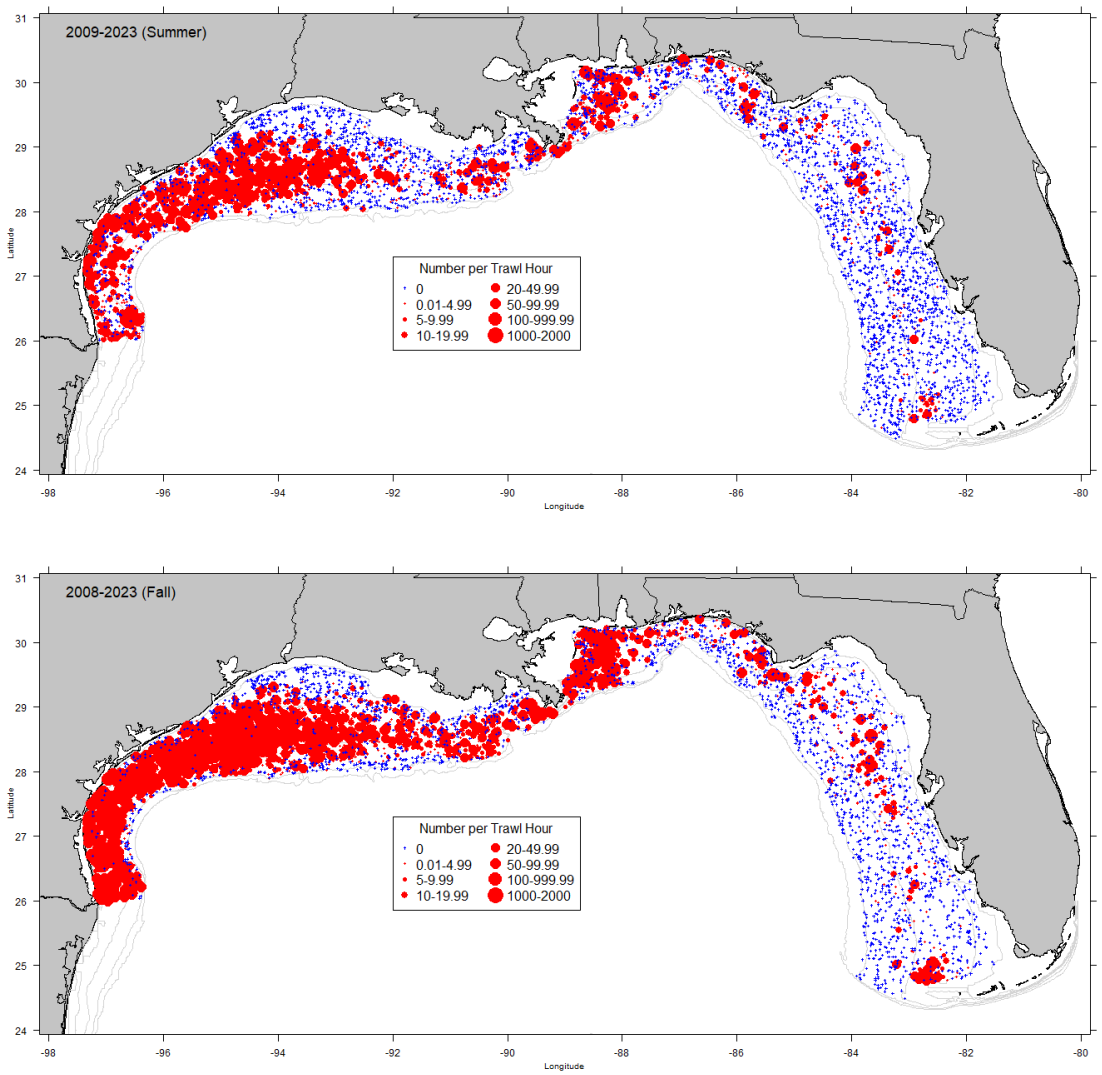


Figure 2. Stations sampled from 2009 to 2023 during the Summer (top) SEAMAP Groundfish Survey and from 2008 to 2023 during the Fall (bottom) SEAMAP Groundfish Surveys with the CPUE for red snapper.

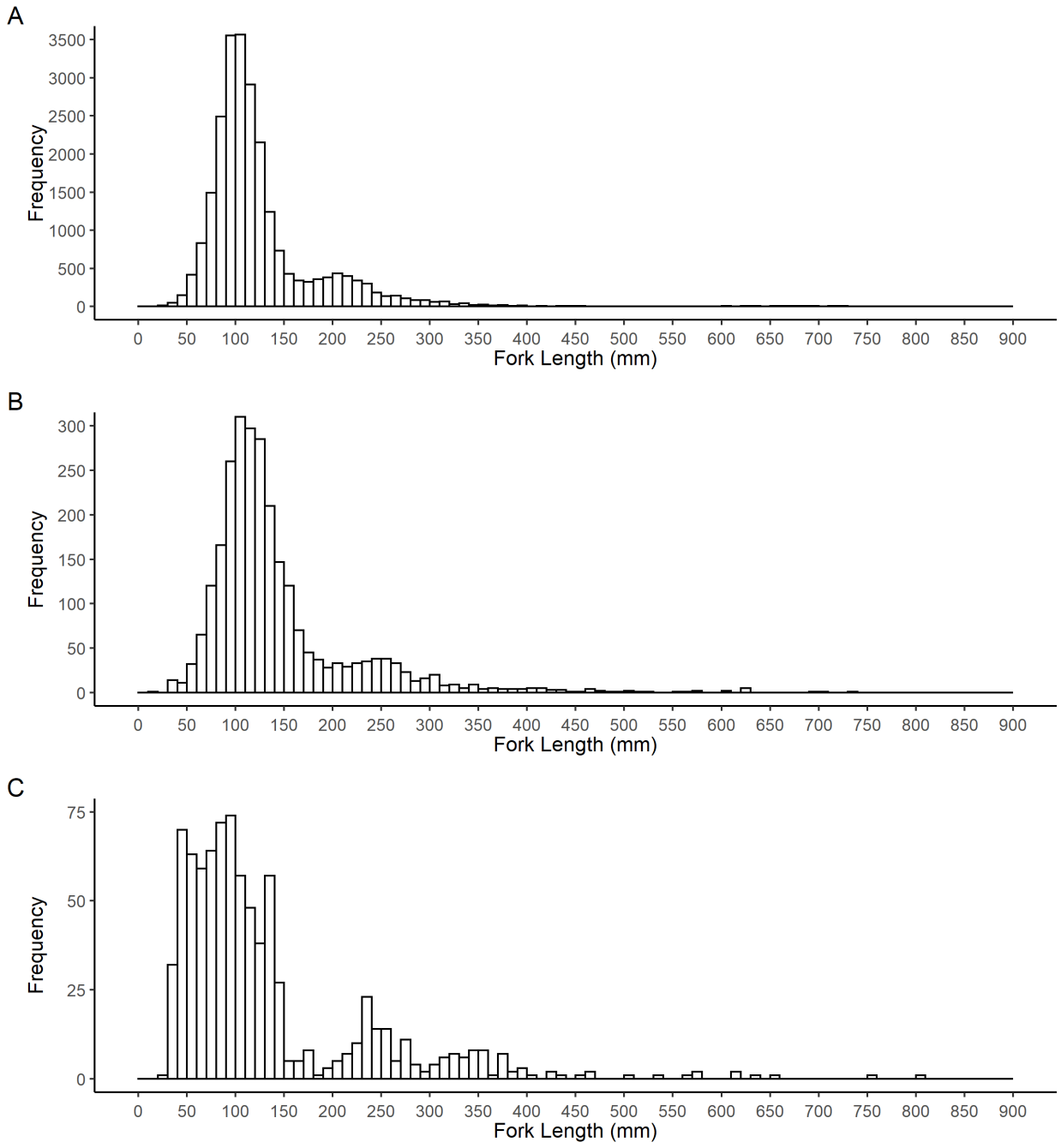


Figure 3. Length frequency histogram for red snapper captured during SEAMAP Fall Groundfish Survey **A.** wGOM (2008-2023), **B.** cGOM (2008-2023), and **C.** eGOM (2008-2023).

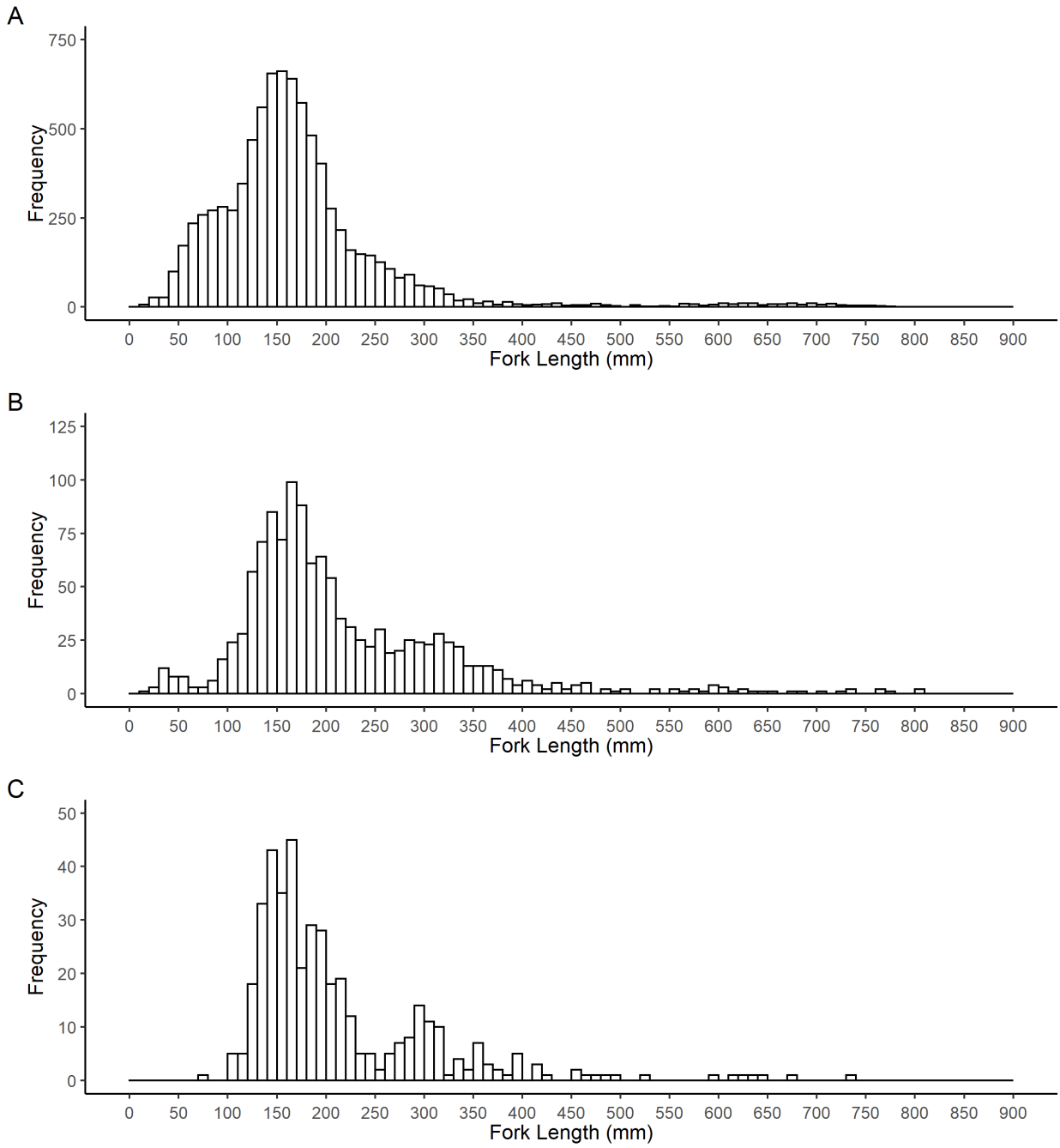


Figure 4. Length frequency histogram for red snapper captured during SEAMAP Summer Groundfish Survey **A.** wGOM (2009-2023), **B.** cGOM (2009-2023), and **C.** eGOM (2009-2023)

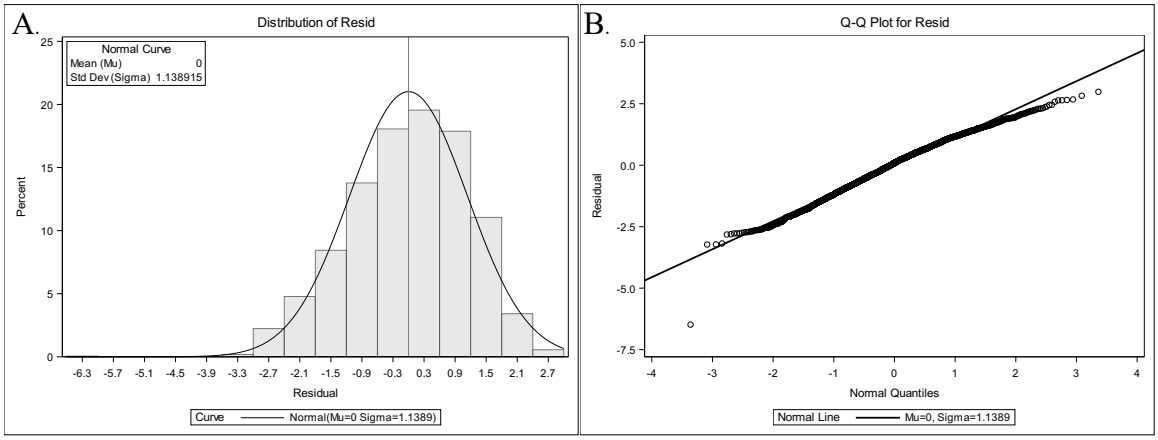


Figure 5. Diagnostic plots for lognormal component of the red snapper SEAMAP Fall Groundfish Survey (wGOM, 2008-2016) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

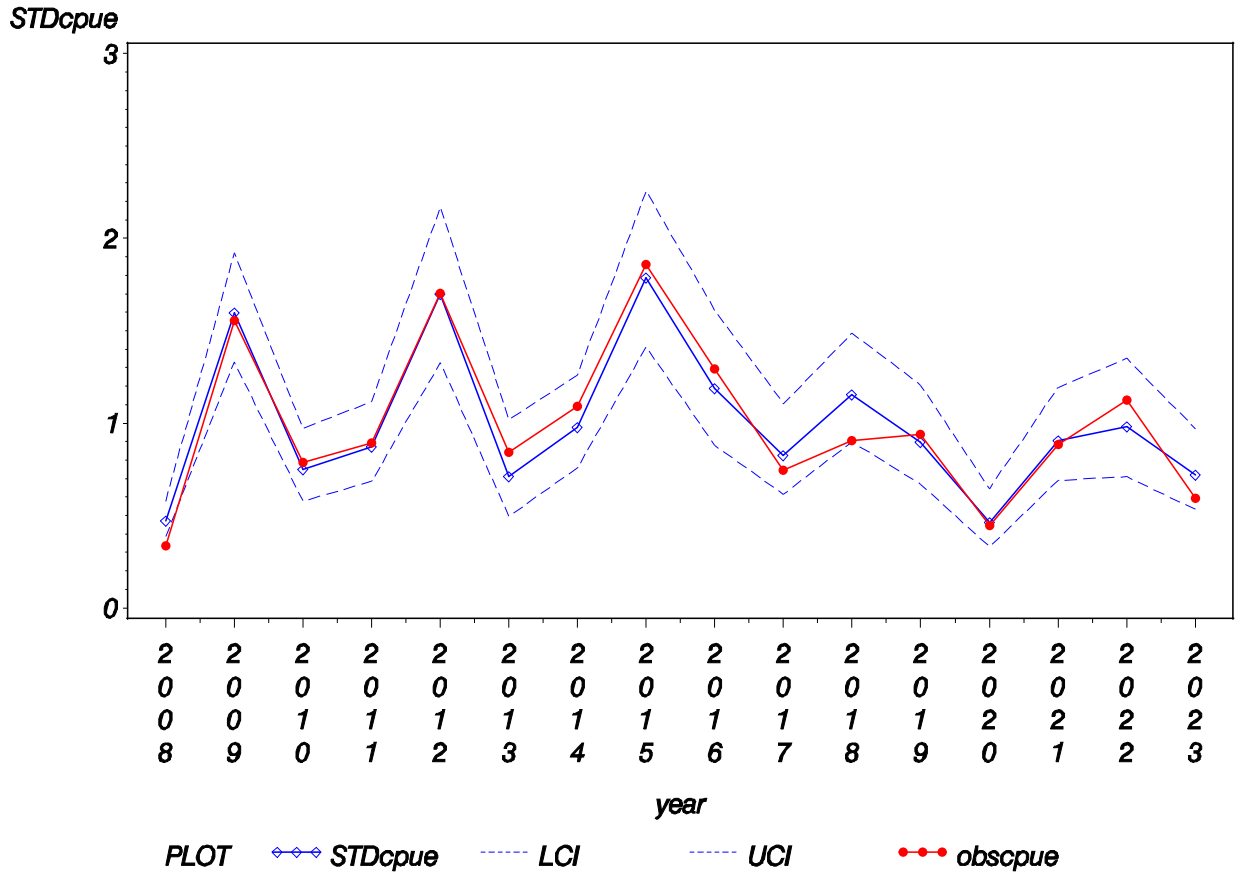


Figure 6. Annual index of abundance for red snapper from the SEAMAP Fall Groundfish Survey (wGOM, 2008-2023)

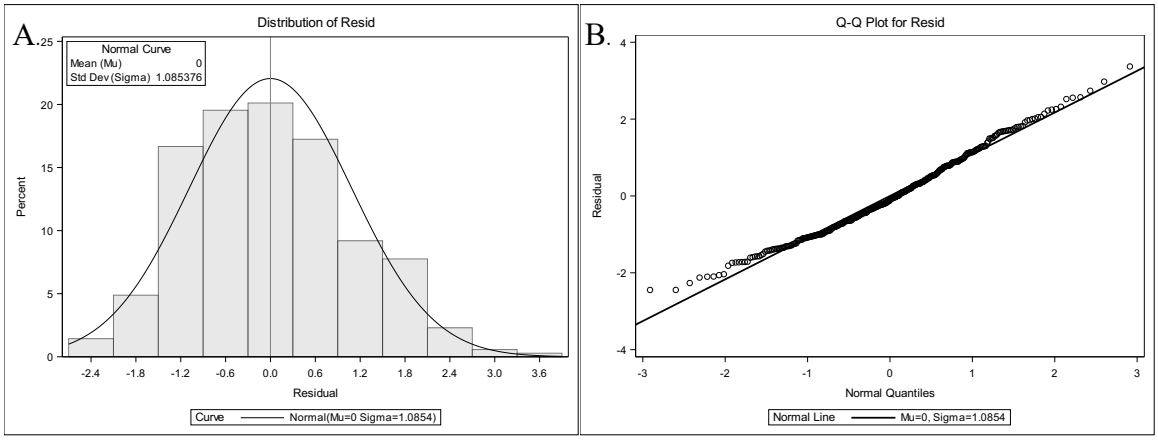


Figure 7. Diagnostic plots for lognormal component of the red snapper SEAMAP Fall Groundfish Survey (cGOM, 2008-2023) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

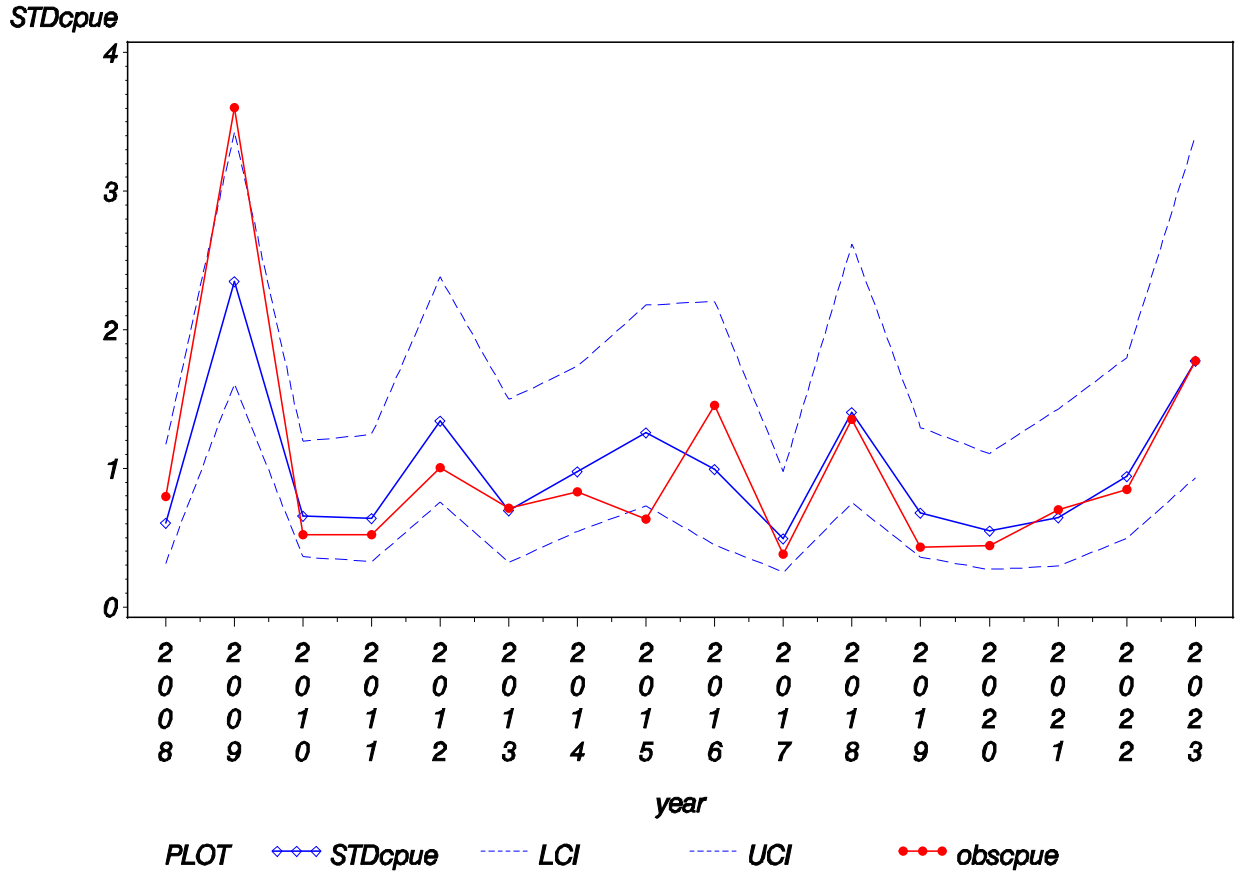


Figure 8. Annual index of abundance for red snapper from the SEAMAP Fall Groundfish Survey (cGOM, 2008-2023).

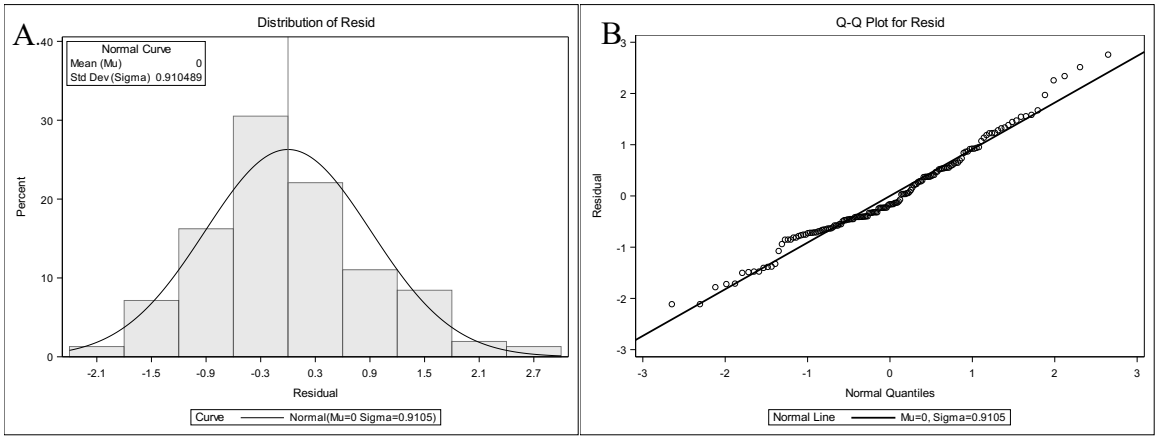


Figure 9. Diagnostic plots for lognormal component of the red snapper SEAMAP Fall Groundfish Survey (eGOM, 2008-2023) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

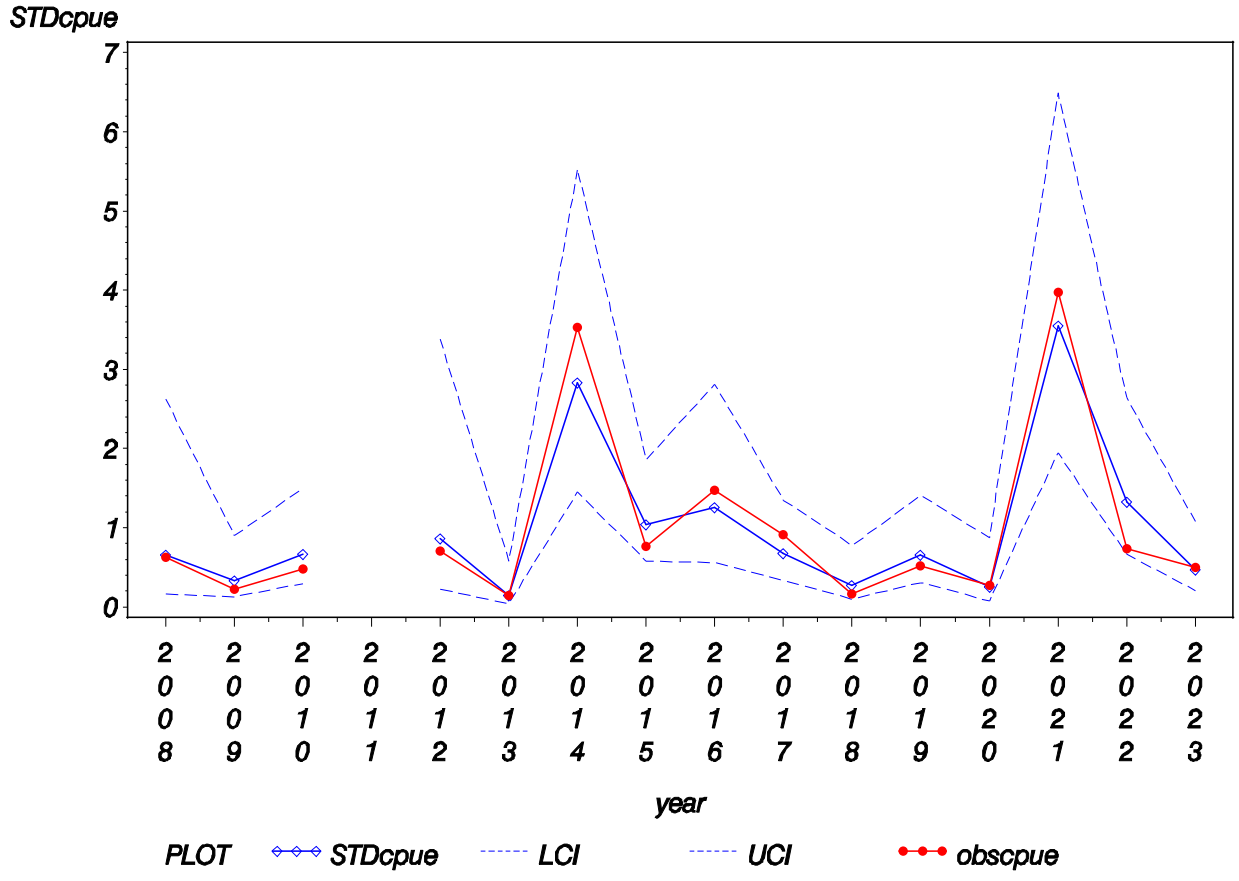


Figure 10. Annual index of abundance for red snapper from the SEAMAP Fall Groundfish Survey (eGOM, 2008-2023).

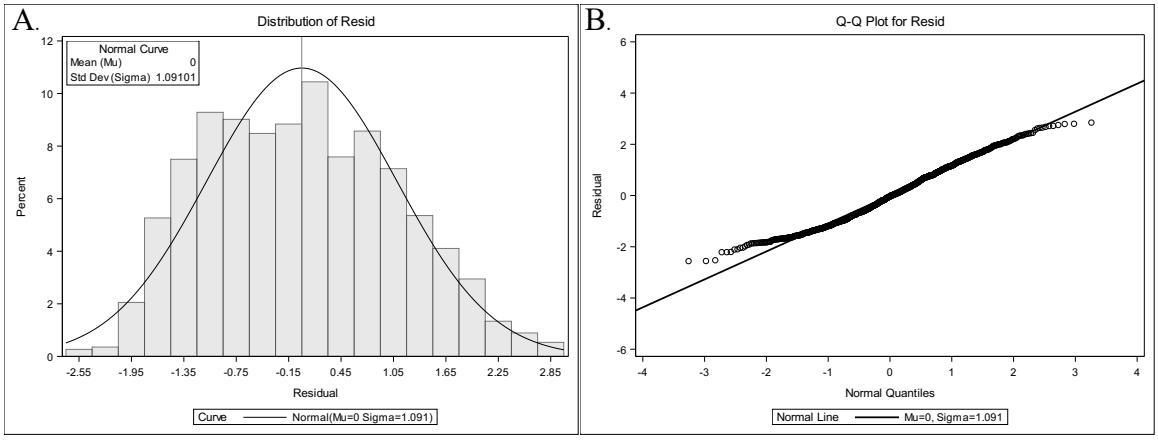


Figure 11. Diagnostic plots for lognormal component of the red snapper SEAMAP Summer Groundfish Survey (wGOM, 2009-2023) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

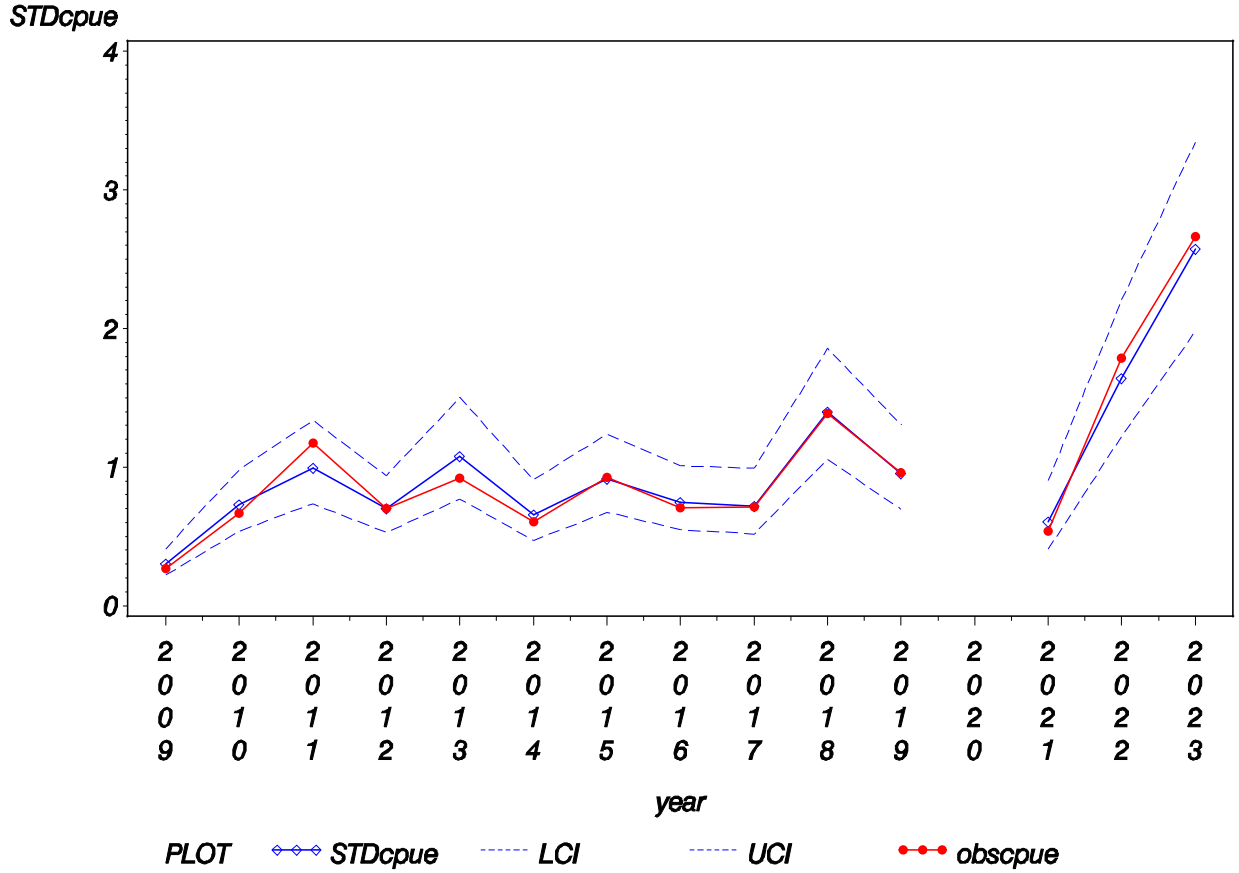


Figure 12. Annual index of abundance for red snapper from the SEAMAP Summer Groundfish Survey (wGOM, 2009-2023).

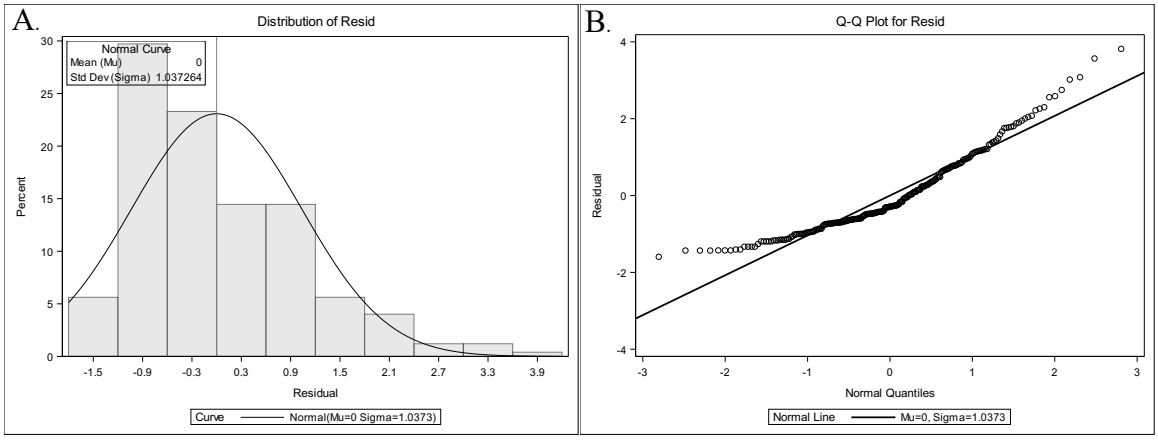


Figure 13. Diagnostic plots for lognormal component of the red snapper SEAMAP Summer Groundfish Survey (cGOM, 2009-2023) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

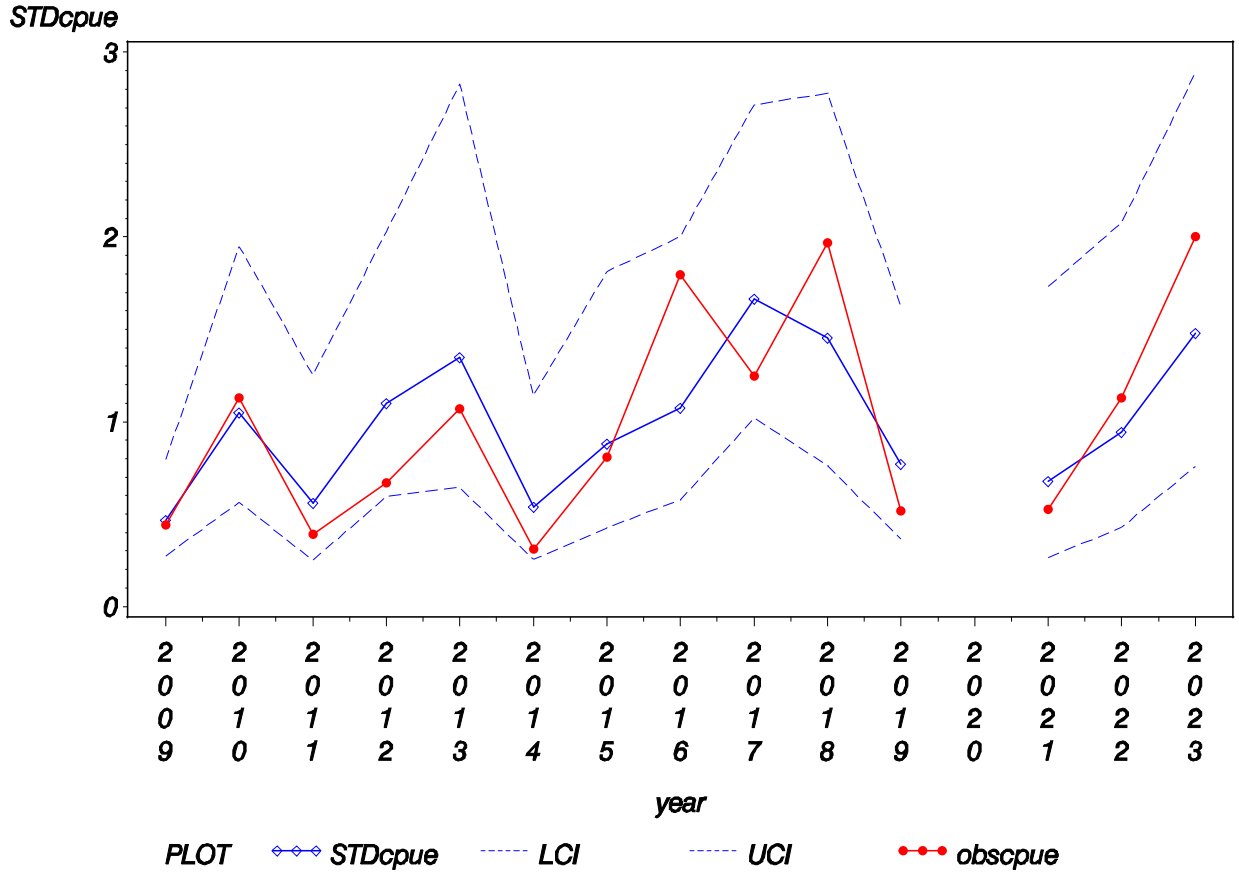


Figure 14. Annual index of abundance for red snapper from the SEAMAP Summer Groundfish Survey (cGOM, 2009-2023).

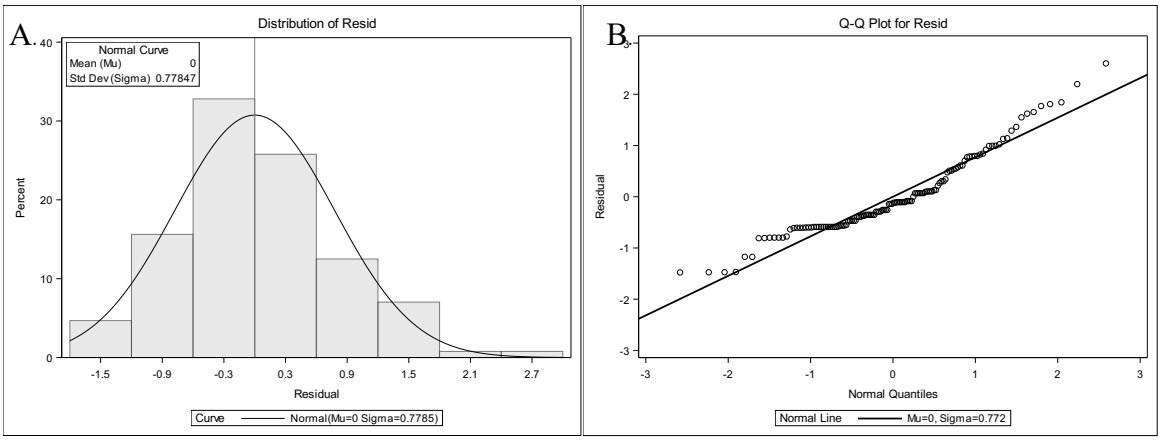


Figure 15. Diagnostic plots for lognormal component of the red snapper SEAMAP Summer Groundfish Survey (eGOM, 2009-2023) model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

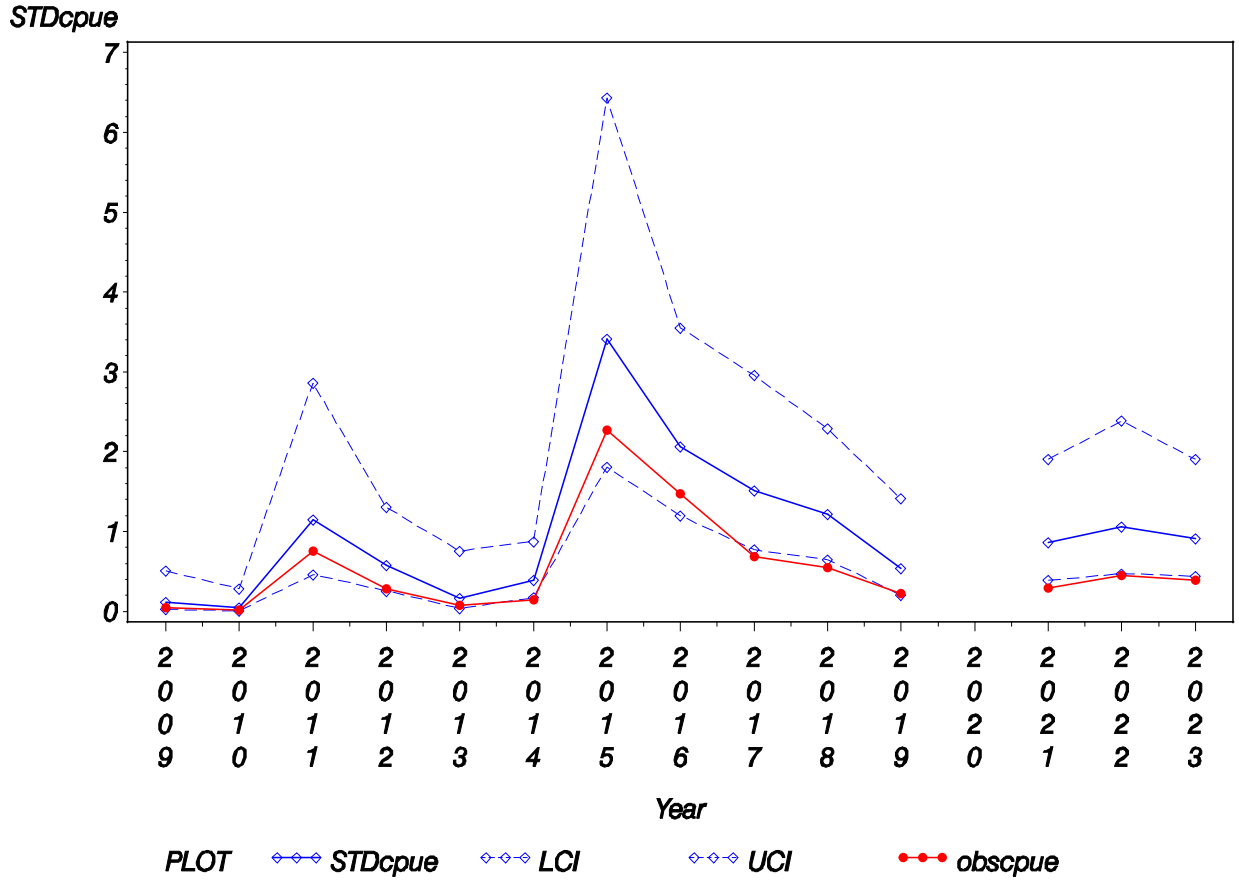


Figure 16. Annual index of abundance for red snapper from the SEAMAP Summer Groundfish Survey (eGOM, 2009-2023).

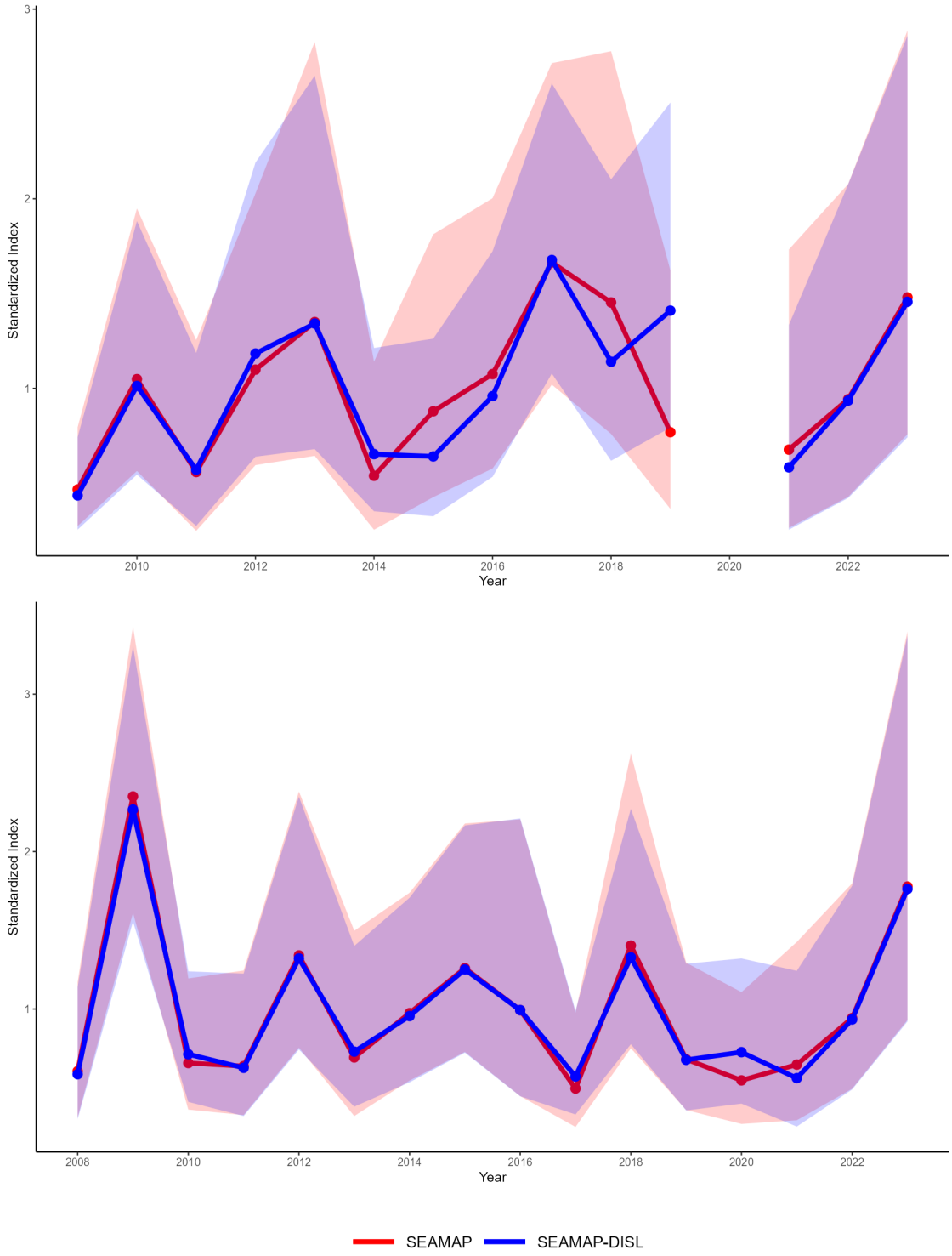


Figure 17. Comparison of the red snapper abundance indices from the SEAMAP Groundfish Surveys (red) and SEAMAP Groundfish Surveys with DISL Surveys (blue) for the summer (top) and fall (bottom).

Appendix

Appendix Table 1. Summary of the factors used in constructing the red snapper abundance index from the Fall Groundfish Surveys wGOM (2008-2023) data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Time of Day	Day	1171	776	0.66268	21.5685
Time of Day	Night	1261	835	0.66217	22.5282
Year	2008	286	177	0.61888	7.4749
Year	2009	273	200	0.73260	34.7313
Year	2010	176	105	0.59659	17.5942
Year	2011	177	115	0.64972	19.9068
Year	2012	132	103	0.78030	37.9759
Year	2013	91	56	0.61538	18.8252
Year	2014	146	102	0.69863	24.3856
Year	2015	144	113	0.78472	41.5058
Year	2016	118	74	0.62712	28.8772
Year	2017	143	84	0.58741	16.6520
Year	2018	142	102	0.71831	20.2458
Year	2019	137	82	0.59854	20.9670
Year	2020	121	66	0.54545	9.9900
Year	2021	137	90	0.65693	19.7585
Year	2022	80	64	0.80000	25.0669
Year	2023	129	78	0.60465	13.2173
Stat Zone	13	98	53	0.54082	11.7216
Stat Zone	14	214	131	0.61215	6.0545
Stat Zone	15	224	118	0.52679	5.6463
Stat Zone	16	322	155	0.48137	6.5219
Stat Zone	17	425	235	0.55294	13.1867
Stat Zone	18	385	287	0.74545	30.9895
Stat Zone	19	262	204	0.77863	46.0338
Stat Zone	20	295	251	0.85085	41.3658
Stat Zone	21	207	177	0.85507	29.2584

Appendix Table 2. Summary of the factors used in constructing the red snapper abundance index from the Fall Groundfish Surveys cGOM (2008-2023) data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Stat Zone	7	140	41	0.29286	2.3121
Stat Zone	8	180	50	0.27778	5.2855
Stat Zone	9	117	29	0.24786	1.7887
Stat Zone	10	120	45	0.37500	4.2603
Stat Zone	11	263	183	0.69582	19.5180
Time of Day	D	403	163	0.40447	8.3964
Time of Day	N	417	185	0.44365	8.9810
Year	2008	50	23	0.46000	5.9704
Year	2009	107	63	0.58879	27.0055
Year	2010	73	23	0.31507	3.8896
Year	2011	42	18	0.42857	3.8910
Year	2012	51	23	0.45098	7.5211
Year	2013	41	13	0.31707	5.3161
Year	2014	55	24	0.43636	6.2190
Year	2015	62	27	0.43548	4.7623
Year	2016	36	12	0.33333	10.8865
Year	2017	49	18	0.36735	2.8553
Year	2018	48	20	0.41667	10.1314
Year	2019	51	19	0.37255	3.2479
Year	2020	40	16	0.40000	3.2978
Year	2021	37	13	0.35135	5.2387
Year	2022	42	18	0.42857	6.3269
Year	2023	36	18	0.50000	13.3132

Appendix Table 3. Summary of the factors used in constructing the red snapper abundance index from the Fall Groundfish Surveys eGOM (2008-2023) data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Stat Zone	2	85	22	0.25882	4.81934
Stat Zone	3	230	22	0.09565	1.13092
Stat Zone	4	244	22	0.09016	0.59730
Stat Zone	5	259	45	0.17375	0.95671
Stat Zone	6	243	43	0.17695	2.86107
Time of Day	D	512	66	0.12891	1.12135
Time of Day	N	549	88	0.16029	2.15736
Year	2008	29	3	0.10345	0.93103
Year	2009	66	7	0.10606	0.33138
Year	2010	61	11	0.18033	0.72041
Year	2012	17	3	0.17647	1.05272
Year	2013	49	3	0.06122	0.20830
Year	2014	109	16	0.14679	5.27341
Year	2015	109	21	0.19266	1.13536
Year	2016	37	10	0.27027	2.20285
Year	2017	92	15	0.16304	1.36851
Year	2018	83	6	0.07229	0.24086
Year	2019	88	12	0.13636	0.77259
Year	2020	69	4	0.05797	0.40580
Year	2021	77	19	0.24675	5.94366
Year	2022	78	14	0.17949	1.10256
Year	2023	97	10	0.10309	0.74227

Appendix Table 4. Summary of the factors used in constructing the red snapper abundance index from the Summer Groundfish Surveys wGOM (2009-2023) data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Time of Day	Day	1347	636	0.47216	8.2233
Time of Day	Night	975	484	0.49641	8.1877
Year	2009	301	89	0.29568	2.3338
Year	2010	201	90	0.44776	5.8817
Year	2011	171	85	0.49708	10.3026
Year	2012	176	92	0.52273	6.1589
Year	2013	141	68	0.48227	8.0841
Year	2014	162	72	0.44444	5.3130
Year	2015	168	83	0.49405	8.1408
Year	2016	162	81	0.50000	6.2242
Year	2017	161	74	0.45963	6.2662
Year	2018	135	84	0.62222	12.1804
Year	2019	145	76	0.52414	8.4175
Year	2020	0			
Year	2021	119	50	0.42017	4.7176
Year	2022	135	79	0.58519	15.7204
Year	2023	145	97	0.66897	23.4165
Stat Zone	13	99	22	0.22222	5.1594
Stat Zone	14	201	71	0.35323	4.1772
Stat Zone	15	228	57	0.25000	1.4329
Stat Zone	16	312	97	0.31090	4.3208
Stat Zone	17	393	181	0.46056	7.6623
Stat Zone	18	364	219	0.60165	11.8906
Stat Zone	19	264	163	0.61742	13.1457
Stat Zone	20	267	185	0.69288	13.3179
Stat Zone	21	194	125	0.64433	8.6017

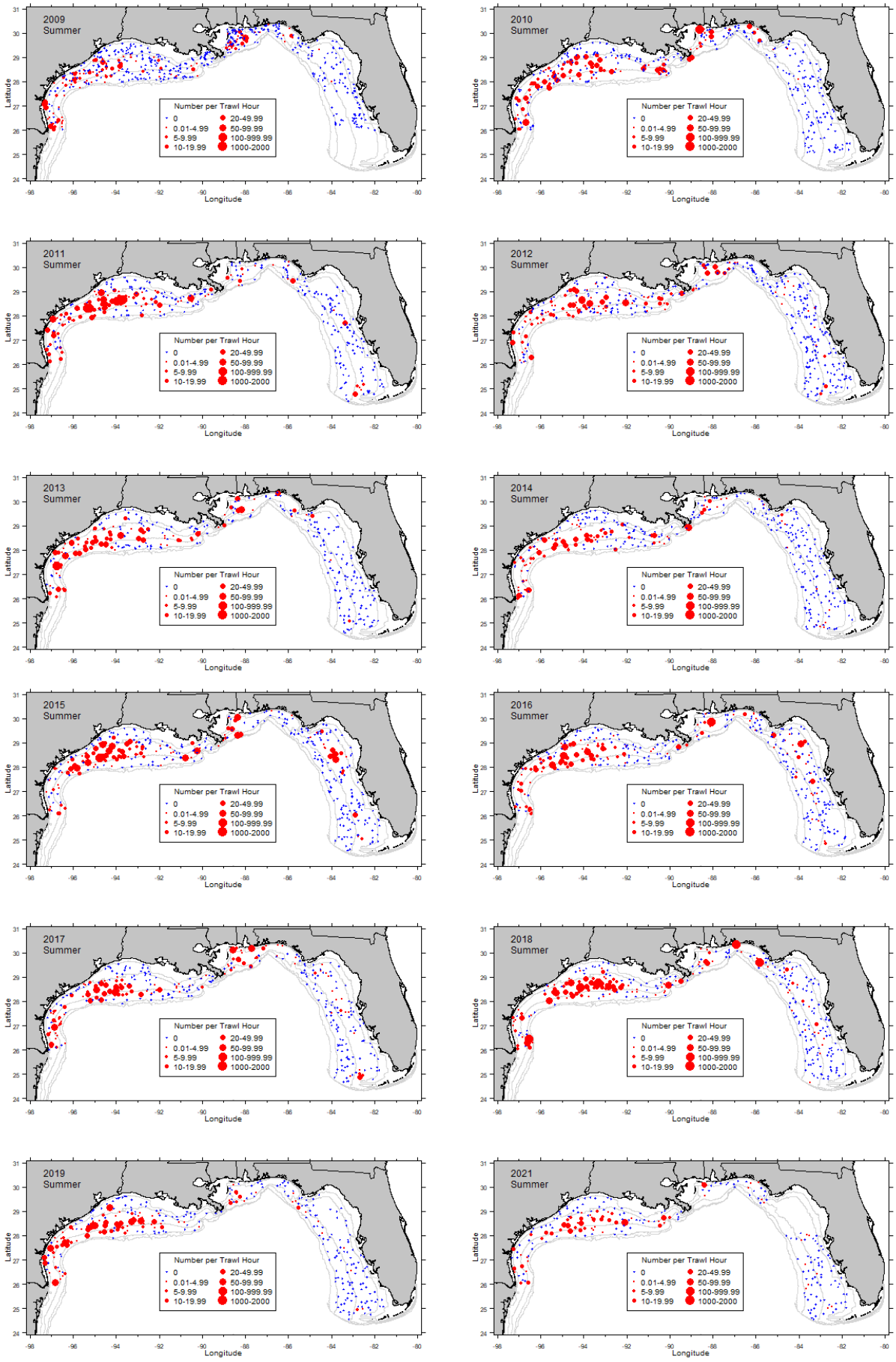
Appendix Table 5. Summary of the factors used in constructing the red snapper abundance index from the Summer Groundfish Surveys cGOM (2009-2023) data.

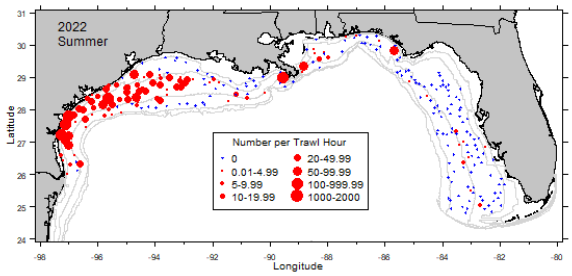
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Time of Day	Day	524	141	0.26908	2.73514
Time of Day	Night	350	108	0.30857	4.22964
Year	2009	140	33	0.23571	1.56541
Year	2010	71	21	0.29577	4.00565
Year	2011	52	12	0.23077	1.38462
Year	2012	80	21	0.26250	2.36514
Year	2013	49	14	0.28571	3.79592
Year	2014	65	14	0.21538	1.10717
Year	2015	74	15	0.20270	2.86420
Year	2016	64	20	0.31250	6.37240
Year	2017	62	30	0.48387	4.41419
Year	2018	54	18	0.33333	6.97512
Year	2019	51	14	0.27451	1.83234
Year	2020	0			
Year	2021	28	8	0.28571	1.85691
Year	2022	39	12	0.30769	3.99838
Year	2023	45	17	0.37778	7.09673
Stat Zone	7	154	27	0.17532	0.79025
Stat Zone	8	188	37	0.19681	1.97478
Stat Zone	9	139	27	0.19424	1.86524
Stat Zone	10	132	33	0.25000	2.08247
Stat Zone	11	261	125	0.47893	7.22788

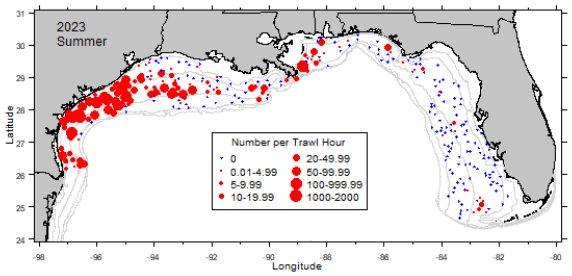
Appendix Table 6. Summary of the factors used in constructing the red snapper abundance index from the Summer Groundfish Surveys eGOM (2009-2023) data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
Time of Day	Day	855	77	0.09006	0.49791
Time of Day	Night	631	51	0.08082	0.65886
Year	2009	88	2	0.02273	0.04545
Year	2010	104	1	0.00962	0.01923
Year	2011	106	7	0.06604	0.75472
Year	2012	143	9	0.06294	0.27927
Year	2013	106	2	0.01887	0.07547
Year	2014	123	9	0.07317	0.14616
Year	2015	119	15	0.12605	2.26731
Year	2016	111	20	0.18018	1.47714
Year	2017	99	13	0.13131	0.68478
Year	2018	113	15	0.13274	0.54867
Year	2019	101	6	0.05941	0.21759
Year	2020	0			
Year	2021	76	9	0.11842	0.28947
Year	2022	94	9	0.09574	0.44681
Year	2023	103	11	0.10680	0.38835
Stat Zone	2	117	18	0.15385	0.90590
Stat Zone	3	371	25	0.06739	0.26899
Stat Zone	4	366	23	0.06284	0.30601
Stat Zone	5	324	25	0.07716	0.55556
Stat Zone	6	308	37	0.12013	1.11581

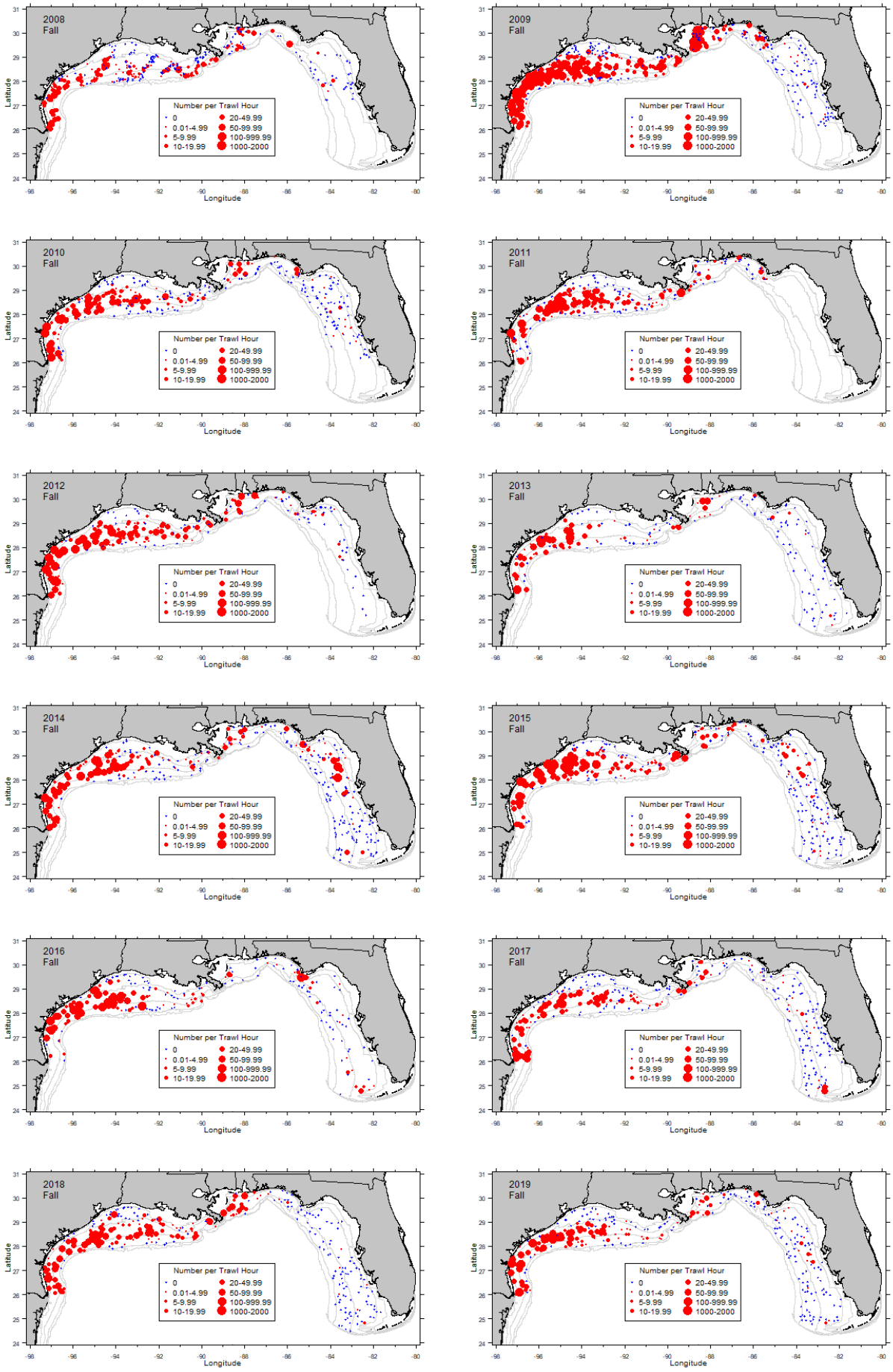
Appendix Figure 1. Annual survey effort and catch of red snapper from the SEAMAP Summer Groundfish Surveys.

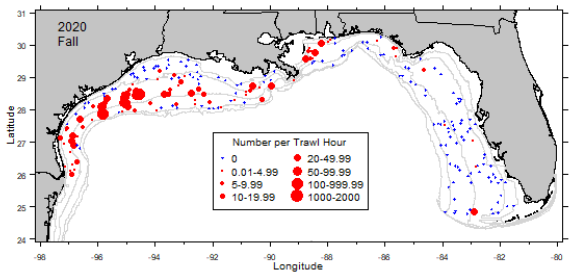


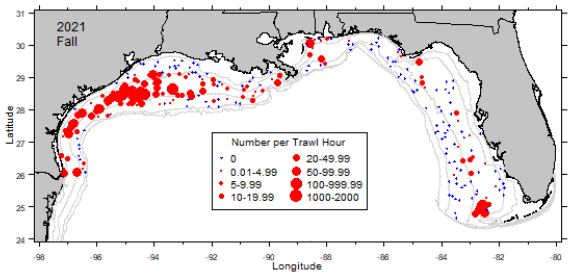

2022
Summer
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-999.99
1000-2000
Latitude
Longitude

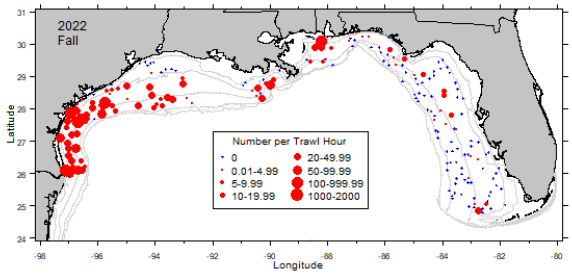

2023
Summer
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-999.99
1000-2000
Latitude
Longitude

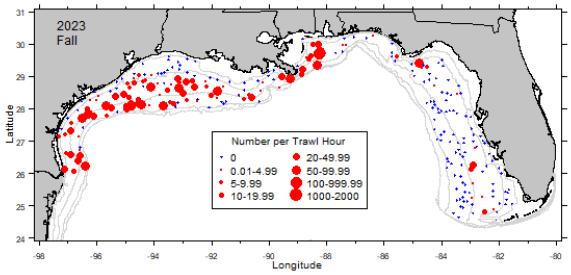
Appendix Figure 2. Annual survey effort and catch of red snapper from the SEAMAP Fall Groundfish Surveys.




2020
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-999.99
1000-2000
Latitude
Longitude


2021
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-999.99
1000-2000
Latitude
Longitude


2022
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-999.99
1000-2000
Latitude
Longitude


2023
Fall
Number per Trawl Hour
0
0.01-4.99
5-9.99
10-19.99
20-49.99
50-99.99
100-999.99
1000-2000
Latitude
Longitude

Addendum

During the SEDAR 98 Data Workshop, questions were raised concerning the uptick in red snapper abundance indices in the summer of 2022 and 2023. Sampling during these two surveys years was conducted several months later than usual (August) due to issues with the NOAA Ship *Oregon II*. Due to the delay in sampling, the survey was found to be catching more age 0 red snapper than are usually encountered during the typical summer survey time frame (Addendum Figure 1). To account for the delay in sampling, all red snapper measuring less than 130 mm in 2022 and 120 mm in 2023 were removed from the data and new abundance indices were calculated following the methods described in the main document.

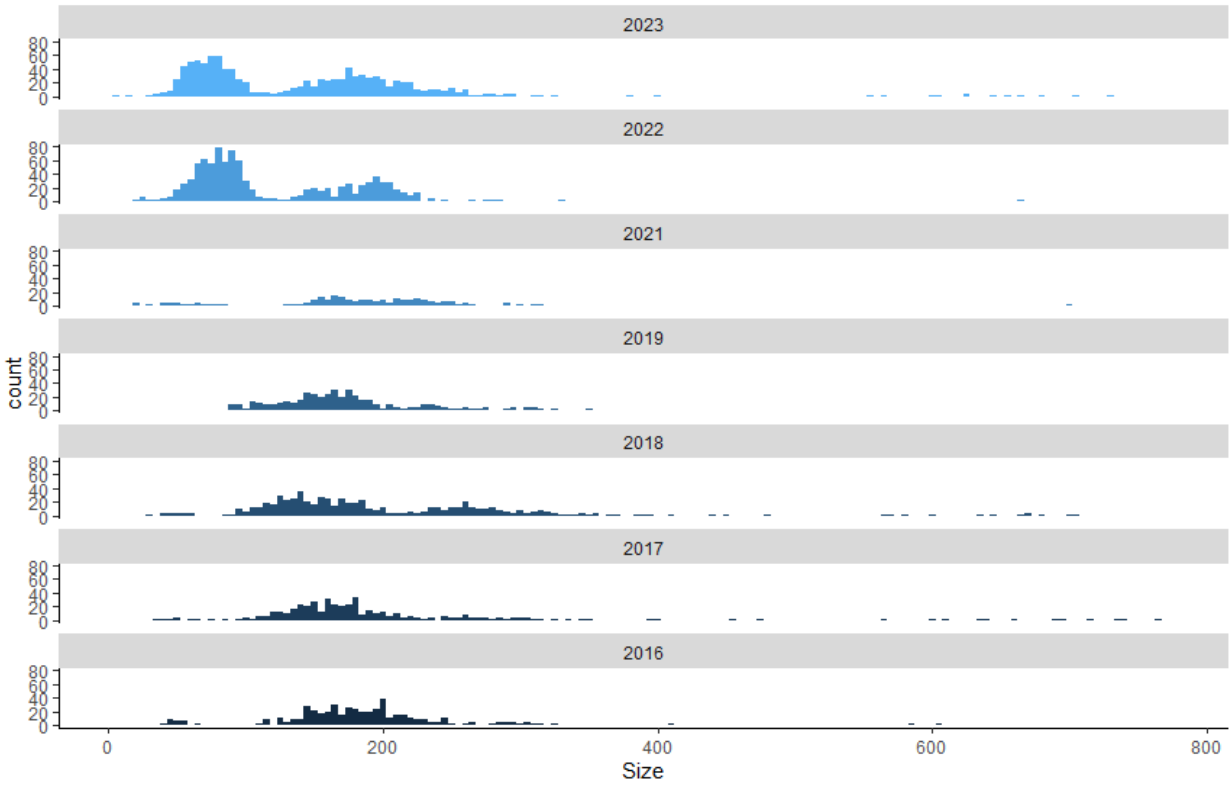
For the modified SEAMAP Summer Groundfish Survey (wGOM, 2009-2023) abundance index of red snapper, year, depth and SSZ were retained in both the binomial submodel and year and SSZ were retained in the lognormal submodel. Addendum Table 1 summarizes the backward selection process and the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 10,191.3 and 3,229.0, respectively. Annual abundance indices are presented in Addendum Table 2 and Addendum Figure 2.

Addendum Table 1. Summary of backward selection procedure for building delta-lognormal submodels for red snapper modified SEAMAP Summer Groundfish Survey (wGOM, 2009-2023) index of relative abundance.

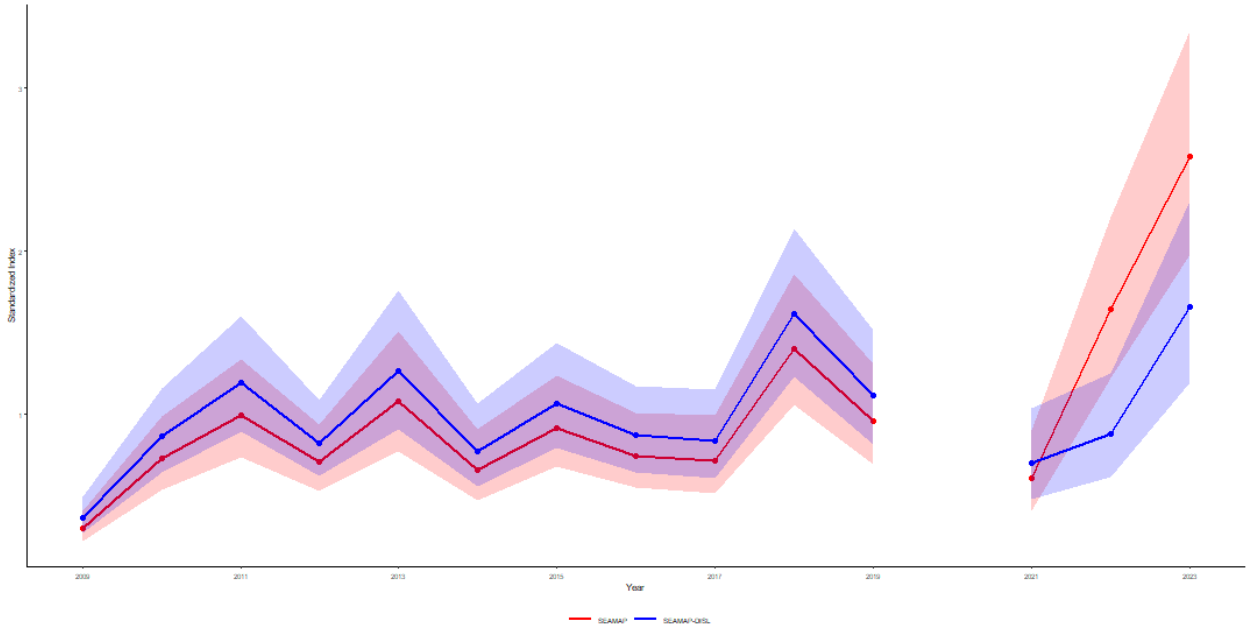
Model Run #1	*Binomial Submodel Type 3 Tests (AIC 10197.4)*						*Lognormal Submodel Type 3 Tests (AIC 3238.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	2298	56.41	4.34	<.0001	<.0001	13	1046	4.21	<.0001
Depth	1	2298	26.04	26.04	<.0001	<.0001	1	1046	3.66	0.0560
Statistical Zone	8	2298	181.60	22.70	<.0001	<.0001	8	1046	7.35	<.0001
Time of Day	1	2298	2.28	2.28	0.1312	0.1314	1	1046	1.57	0.2100
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 10191.3)*						*Lognormal Submodel Type 3 Tests (AIC 3236.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	2299	55.82	4.29	<.0001	<.0001	13	1047	4.17	<.0001
Depth	1	2299	26.06	26.06	<.0001	<.0001	1	1047	3.80	0.0515
Statistical Zone	8	2299	181.31	22.66	<.0001	<.0001	8	1047	7.24	<.0001
Time of Day				Dropped				Dropped		
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 10191.3)*						*Lognormal Submodel Type 3 Tests (AIC 3229.0)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	13	2299	55.82	4.29	<.0001	<.0001	13	1048	4.21	<.0001
Depth	1	2299	26.06	26.06	<.0001	<.0001		Dropped		
Statistical Zone	8	2299	181.31	22.66	<.0001	<.0001	8	1048	7.78	<.0001
Time of Day				Dropped				Dropped		

Addendum Table 2. Index of red snapper abundance developed using the delta-lognormal (DL) model for modified SEAMAP Summer Groundfish Survey (wGOM, 2009-2023). 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
2009	0.29568	301	2.3501	0.36361	0.15274	0.26837	0.49265
2010	0.44776	201	5.5645	0.86093	0.14849	0.64076	1.15675
2011	0.49708	171	7.7097	1.19283	0.14733	0.88982	1.59904
2012	0.52273	176	5.2861	0.81785	0.14107	0.61765	1.08294
2013	0.48227	141	8.1564	1.26194	0.16587	0.90771	1.75442
2014	0.44444	162	4.9819	0.77079	0.16175	0.55892	1.06298
2015	0.49405	168	6.8784	1.06421	0.14954	0.79041	1.43285
2016	0.50000	162	5.6088	0.86779	0.15053	0.64328	1.17065
2017	0.45963	161	5.4048	0.83622	0.16044	0.60792	1.15025
2018	0.62222	135	10.4501	1.61682	0.13944	1.22497	2.13401
2019	0.52414	145	7.1820	1.11119	0.15522	0.81615	1.51290
2020	0.42017	119	4.5391	0.70229	0.19744	0.47496	1.03842
2021	0.42963	135	5.6599	0.87569	0.17885	0.61408	1.24874
2022	0.46897	145	10.7152	1.65784	0.16594	1.19231	2.30515
2023	0.29568	301	2.3501	0.36361	0.15274	0.26837	0.49265



Addendum Figure 1. Comparison of red snapper length frequency distribution between 2016 and 2023 for the SEAMAP Summer Groundfish Survey. Surveys in 2022 and 2023 were conducted outside the normal time frame of the rest of the survey years.



Addendum Figure 2. Comparison of the red snapper abundance indices from the SEAMAP Summer Groundfish Surveys (red) and modified SEAMAP Summer Groundfish Surveys (blue). The modified SEAMAP Summer Groundfish Surveys had all age 0 red snapper removed from 2022 and 2023.