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SEDAR 42-DW-05

7 November 2014
Updated: 26 November 2014

Please cite this document as:

Pollack, A.G. and G. Walter Ingram, Jr. 2014. Red Grouper Abundance Indices from SEAMAP Groundfish Surveys in the Northern Gulf of Mexico. SEDAR42-DW-05. SEDAR, North Charleston, SC. 26 pp.

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

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Abstract

The Southeast Fisheries Science Center Mississippi Laboratories and state partners have conducted groundfish surveys since 1972 in the northern Gulf of Mexico during the summer and fall under several sampling programs. In 1987, both groundfish surveys were brought under the Southeast Area Monitoring and Assessment Program (SEAMAP). These fisheries independent data were used to develop abundance indices for red grouper (Epinephelus morio). Since red grouper had only been observed in the eastern Gulf of Mexico, the time series had to be limited to 2008 – 2013, since previously no sampling was conducted in the eastern Gul f of Mexico.

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories (MSLABS) and state partners have conducted standardized 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 grouper (*Epinephelus morio*).

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 fathoms), shrimp statistical zones (between 88° and 97° W longitude, statistical zones 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 shrimp statistical zone with a weighting by area. Other notable changes included a standardized 30 minute 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. Recently, a new modification was added to the survey design, a depth stratification of 5 - 20 fathoms and 20 – 60 fathoms.

Data

A total of 18,924 stations were sampled from 1972- 2013 with 8,085 and 10,839 stations sampled during the summer and fall survey, respectively (Tables 1 and 2). The total number of stations used in the analysis was 718 and 308 stations from the summer and fall survey, respectively. Trawl data was obtained from the MSLABS trawl unit leader (Gilmore Pellegrin) 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 were obtained from the SEFSC Panama City Laboratory.

Data Exclusions

Data was limited by several factors:

(1) No problems with tow (i.e. net torn, doors crossed, etc.).
(2) Depths between 5 and 60 fathoms.
(3) Within shrimp statistical zones 2 – 8 (east of 86° W) (no catch of red grouper outside of these zones).
(4) Sampled with a 40 ft shrimp trawl (Texas uses a 20 ft shrimp trawl and data are not used).
(5) Sampled between 2008 and 2013 (prior to 2008, no samples were taken east of shrimp statistical zone 10).

Data Caveats

The survey area has been expanded throughout the course of the fall time series. Prior to 1987, the areas of East Louisiana and Mississippi/Alabama (Figure 1) were considered the primary sampling area, areas directly west and east of the primary were designated the secondary sampling areas; East Florida and Texas were not sampled. During this time, triplicate 10 minute tows were done at each station. For the purpose of this analysis, those stations were collapsed down and treated as a single station.

From 1987 – 2008 (summer), the area sampled was from Brownsville, TX to Mobile Bay, AL. Sampling rarely extended past Mobile Bay due to an increase in the number of hangs. During this time, tow length was dependent on how long it took to cover a full depth stratum (defined

above). However, single tows never exceeded 55 minutes. Full details about this survey can be found in Nichols (2004).

Beginning in 2008, sampling was expanded to cover the eastern GOM, down to the Florida Keys. The other changes to the survey are outlined above in the survey design section and in Pollack and Ingram (2010).

Index Construction

Delta-lognormal modeling methods were used to estimate relative abundance indices for red grouper (Lo *et al*. 1992). 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 (Lo *et al*. 1992).

The delta-lognormal index of relative abundance (I_y) as described by Lo *et al*. (1992) was estimated as:

(1) $$I_y = c_y p_y,$$

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

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

and

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

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

(4) $$V(I_y) \approx V(c_y)p_y^2 + c_y^2 V(p_y) + 2c_y p_y \mathrm{Cov}(c, p),$$

where:

(5) $$\mathrm{Cov}\left(c, p\right) \approx \rho_{c,p}\left[\mathrm{SE}\left(c_y\right)\mathrm{SE}\left(p_y\right)\right],$$

and $\rho_{c,p}$ denotes correlation of *c* and *p* among years.

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 (SEAMAP Summer Groundfish)

Year: 2008 – 2013
Depth: 5-60 fathoms (continuous)
Shrimp Statistical Zone: Zones 2 - 8
Time of Day: Day, Night
Season: Summer, Fall

Results and Discussion

Size and Age

The distribution of red grouper is presented in Figure 1, with seasonal/annual abundance and distribution presented in the Appendix Figure 1. The total number of red grouper captured ranged from 17 to 171 in the summer (Table 3) and 0 to 127 in the fall (Table 4). Of the 622 red grouper captured during the summer survey, a total of 618 were measured with an average total length of 302 mm. During the fall survey, 238 red grouper were captured, with 237 measured, with an average total length of 340 mm. The length frequency distribution of red grouper captured is shown in Figure 2. Analysis of otoliths collected from red grouper indicated that most (89%) are less than five years old (Figure 3).

Index of Abundance

For the SEAMAP abundance index of red grouper, the nominal CPUE and number of stations with a positive catch are presented in Figure 4. Year, depth and shrimp statistical zone were retained in both the binomial submodel and the lognormal submodel. A summary of the factors used in the analysis is presented in Appendix Table 1. Table 5 summarizes the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 5715.8 and 638.4, respectively. There was an increase in AIC with each run of the binomial submodel, however since the factors removed were not significant, this increase was deemed acceptable. The diagnostic plots for the binomial and lognormal submodels are shown in Figures 5-7, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Table 6 and Figure 8.

Literature Cited

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Table 1. Number of stations sampled by shrimp statistical zone during the summer SEAMAP groundfish survey from 1982-2012.

	Shrimp Statistical Zone																			
Year	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
1982									14	36	24	26	8	1	11	30	10	3	23	***186***
1983							5	19	8	26		6	16	19	25	24	21	5	17	***191***
1984									13	36	10	16	16	22	17	15	23	28	14	***210***
1985									10	48	11	27	12	10	7	7	12	11	10	***165***
1986									17	49	4	20	14	8	11	8	11	14	6	***162***
1987									27	58	8	34	21	25	20	16	25	28	19	***281***
1988									17	46	10	14	9	19	24	14	25	28	23	***229***
1989									21	30	8	13	18	25	7	15	20	29	24	***210***
1990										65	18	31	17	23	16	20	23	24	20	***257***
1991										44	16	41	13	23	22	24	18	23	26	***250***
1992									1	44	2	36	30	20	25	12	31	26	20	***247***
1993										44	22	29	19	24	19	14	29	24	22	***246***
1994										60	12	27	28	25	17	20	22	26	22	***259***
1995										42	12	26	24	22	23	13	27	26	21	***236***
1996										46	14	34	19	22	18	17	21	26	25	***242***
1997										42	4	26	22	22	23	10	28	26	26	***229***
1998										34	6	28	27	25	18	14	22	36	17	***227***
1999										43	11	31	26	20	23	13	25	32	20	***244***
2000										43	11	27	19	19	27	8	29	31	21	***235***
2001										34	15	24	28	13	3	10	9	17	21	***174***
2002										44	15	34	21	27	19	15	25	29	22	***251***
2003										42	17	26	8	2	17	20	22	26	23	***203***
2004										38	19	28	21	20	25	21	19	25	21	***237***
2005										31	10	9	23	16	21	5	28	22	27	***192***
2006										45	17	29	16	20	23	17	23	31	18	***239***
2007										40	12	10	23	22	23	7	29	32	21	***219***
2008			1	8	11	6	11	8	11	42	24	19	27	23	22	17	24	21	29	***304***
2009			36	23	29	16	17	18	24	67	25	20	36	39	46	53	33	29	23	***534***
2010		31	26	21	26	10	12	14	15	22	5	20	16	21	33	34	27	27	19	***379***
2011	11	24	22	20	29	2	15	11	8	10	7	14	17	24	29	29	18	21	13	***324***
2012	12	39	33	29	30	19	16	17	13	16	14	27	27	25	29	27	20	20	15	***428***
2013	9	27	28	24	19	10	11	9	5	11	6	12	14	21	22	22	16	17	12	***295***
Total	***32***	***121***	***146***	***125***	***144***	***63***	***87***	***96***	***204***	***1278***	***389***	***764***	***635***	***647***	***665***	***571***	***715***	***763***	***640***	***8085***

Table 2. Number of stations sampled by shrimp statistical zone during the fall SEAMAP groundfish survey from 1972-2012.

	Shrimp Statistical Zone																		
Year	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	Total
1972									10	55	27	41	34	17						***184***
1973								11	17	98	34	71	39	2						***272***
1974									12	92	35	73	31							***243***
1975										93	33	80	35	32	7					***280***
1976										108	42	79	56	22						***307***
1977										97	31	76	38							***242***
1978									36	101	32	67	58	25						***319***
1979										109	35	72	55	2						***273***
1980									24	85	22	70	32							***233***
1981									21	85	33	66	49	25						***279***
1982									21	102	41	72	37							***273***
1983									17	82	35	63	25							***222***
1984										82	32	64	47	1						***226***
1985									30	63	23	37	53	32	10	20	20	19	19	***326***
1986							20	10	25	34	13	27	14	27	35	26	23	22	21	***297***
1987									13	22	29	29	26	17	15	15	15	18	3	***202***
1988									8	27	10	28	24	18	26	19	21	31	20	***232***
1989										43	16	31	23	22	20	17	22	25	26	***245***
1990										52	20	22	27	22	19	18	22	19	27	***248***
1991										45	16	32	18	20	25	24	19	25	22	***246***
1992										32	15	31	14	25	18	17	27	30	18	***227***
1993										70	14	35	19	26	18	16	25	28	18	***269***
1994										49	17	24	27	25	20	21	23	24	20	***250***
1995										39	14	29	24	24	19	14	26	30	19	***238***
1996										43	11	36	21	17	28	13	25	29	24	***247***
1997										43	18	31	20	26	19	18	23	22	24	***244***
1998										43	28	50	14	34	11	15	24	29	22	***270***
1999										42	9	38	18	29	18	12	28	29	22	***245***
2000										42	10	27	28	20	26	12	30	25	21	***241***
2001										43	14	30	22	26	20	14	27	28	23	***247***
2002									1	49	16	27	26	22	23	14	26	30	21	***255***
2003									1	74	20	20	21	24	22	20	23	25	23	***273***
2004										43	6	23	24	17	27	14	24	30	21	***229***
2005										43	21	30	18	33	18	14	23	24	27	***251***
2006									1	46	7	22	14	18	28	13	23	32	19	***223***
2007										31	15	27	26	18	28	17	20	18	26	***226***

	Shrimp Statistical Zone																			
Year	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	34	16	28	34	42	46	44	19	36	20	***363***
2009			20	21	25	11	21	13	12	47	12	23	23	30	49	47	31	36	22	***443***
2010			9	27	27	18	16	11	14	16	7	15	18	26	31	29	18	19	14	***315***
2011							9	11	6	11	9	25	19	32	31	28	21	19	15	***236***
2012		2	3	6	6	17	10	7	4	9	10	22	15	19	22	22	13	14	11	***212***
2013	4	14	14	11	12	10	10	6	5	10	5	11	9	3	12	16	11	14	9	***186***
Total	***4***	***16***	***46***	***80***	***84***	***60***	***90***	***72***	***282***	***2334***	***853***	***1704***	***1175***	***820***	***691***	***569***	***652***	***730***	***577***	***10839***

Table 3. Summary of the red grouper length data collected during summer SEAMAP groundfish surveys conducted between 2008 and 2013. (Note that prior to 2008, no red grouper were caught.)

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
2008	37	17	17	197	468	274	61
2009	121	171	171	74	578	285	75
2010	126	113	111	137	718	282	98
2011	123	114	114	46	805	308	126
2012	178	142	140	37	838	316	142
2013	128	65	65	73	754	347	146

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured	Overall Mean Fork Length (mm)
6	718	622	618	302

Table 4. Summary of the red grouper length data collected during fall SEAMAP groundfish surveys conducted between 2008 and 2013. (Note that prior to 2008, no red grouper were caught)

Survey Year	Number of Stations	Number Collected	Number Measured	Minimum Fork Length (mm)	Maximum Fork Length (mm)	Mean Fork Length (mm)	Standard Deviation (mm)
2008	37	16	16	79	578	309	106
2009	98	127	127	91	689	328	92
2010	97	76	76	120	631	366	84
2011	9	0	11	119	485	309	109
2012	44	11	7	193	615	382	153
2013	75	7	16	79	578	309	106

Total Number of Years	Total Number of Stations	Total Number Collected	Total Number Measured	Overall Mean Fork Length (mm)
6	380	238	237	340

Table 5. Summary of backward selection procedure for building delta-lognormal submodels for red grouper SEAMAP groundfish survey index of relative abundance from 2008 to 2013.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC 5651.3)*						*Lognormal Submodel Type 3 Tests (AIC 641.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	5	428	19.07	3.79	0.0019	0.0023	5	270	3.62	0.0035
Depth	1	924	77.52	77.52	<.0001	<.0001	1	270	16.19	<.0001
Season	1	770	2.77	2.77	0.0959	0.0963	1	270	1.33	0.2502
StatZone	6	801	68.95	11.48	<.0001	<.0001	6	270	4.37	0.0003
Time of Day	1	953	1.50	1.50	0.2201	0.2204	1	270	1.85	0.1754
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 5701.7)*						*Lognormal Submodel Type 3 Tests (AIC 639.9)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	5	430	18.44	3.67	0.0024	0.0029	5	271	3.39	0.0055
Depth	1	901	76.25	76.25	<.0001	<.0001	1	271	17.01	<.0001
Season	1	746	2.68	2.68	0.1015	0.1019		Dropped		
StatZone	6	760	67.65	11.26	<.0001	<.0001	6	271	4.35	0.0003
Time of Day				Dropped			1	271	1.71	0.1926
Model Run #3	*Binomial Submodel Type 3 Tests (AIC 5715.8)*						*Lognormal Submodel Type 3 Tests (AIC 638.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	5	412	15.86	3.15	0.0072	0.0083	5	272	3.23	0.0076
Depth	1	900	75.86	75.86	<.0001	<.0001	1	272	18.37	<.0001
Season				Dropped				Dropped		
StatZone	6	747	68.96	11.48	<.0001	<.0001	6	272	4.34	0.0003
Time of Day				Dropped				Dropped		

Table 6. Indices of red grouper abundance developed using the delta-lognormal model for SEAMAP groundfish survey from 2008-2013. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

Survey Year	Frequency	*N*	DL Index	Scaled Index	CV	LCL	UCL
2008	0.18919	74	0.55825	0.77818	0.47403	0.31624	1.91486
2009	0.35616	219	1.34387	1.87331	0.28617	1.06887	3.28319
2010	0.30942	223	0.79193	1.10393	0.31523	0.59648	2.04308
2011	0.22727	132	0.71504	0.99675	0.35747	0.49817	1.99432
2012	0.25225	222	0.61229	0.85351	0.34154	0.43924	1.65851
2013	0.18719	203	0.28288	0.39433	0.38602	0.18713	0.83095

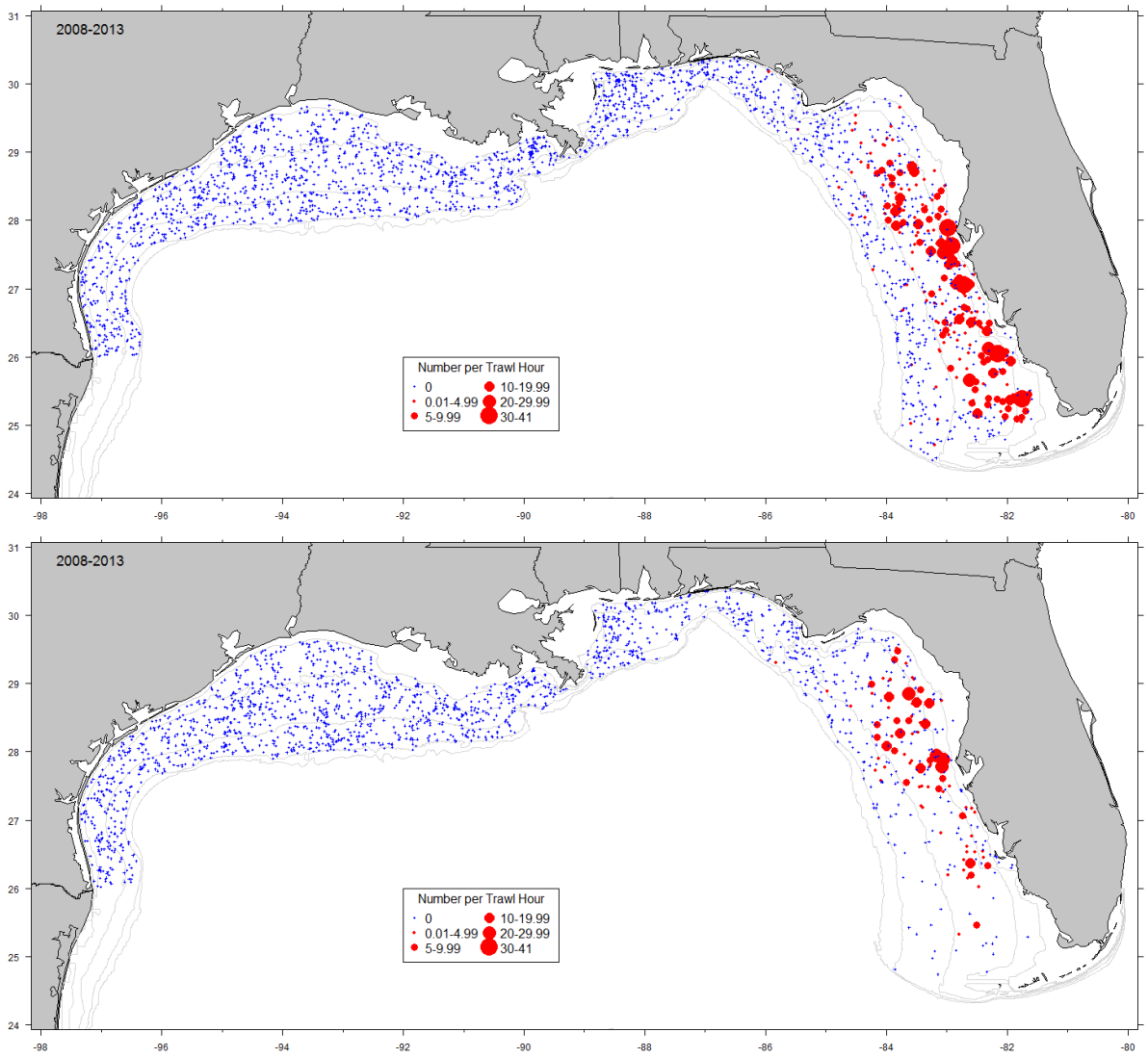


Figure 1. Stations sampled from 2008 to 2013 during the Summer (top) and Fall (bottom) SEAMAP Groundfish Survey with the CPUE for red grouper.

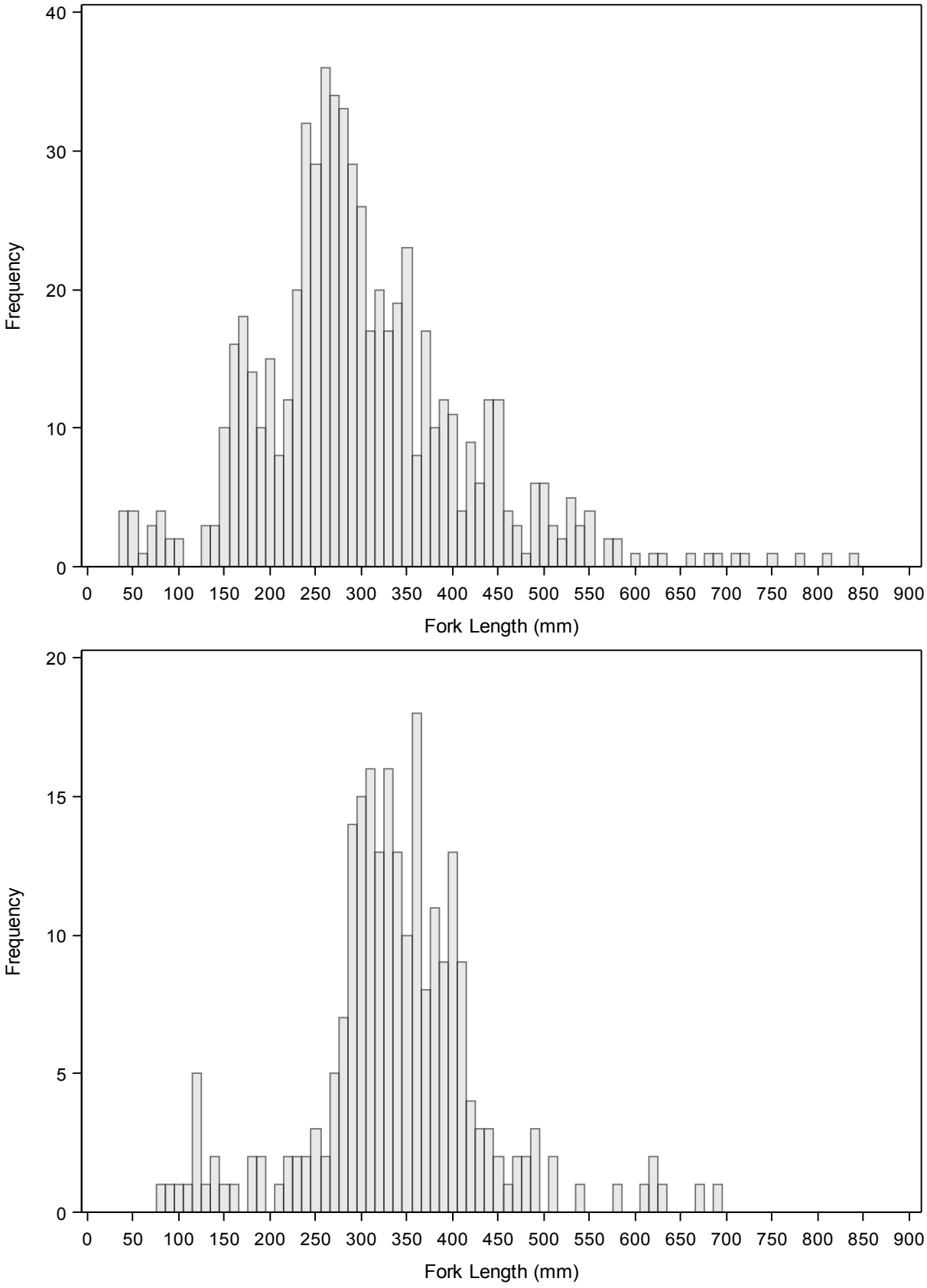


Figure 2. Length frequency histograms for red grouper captured Summer (top) and Fall (bottom) SEAMAP Groundfish surveys from 2008 - 2013.

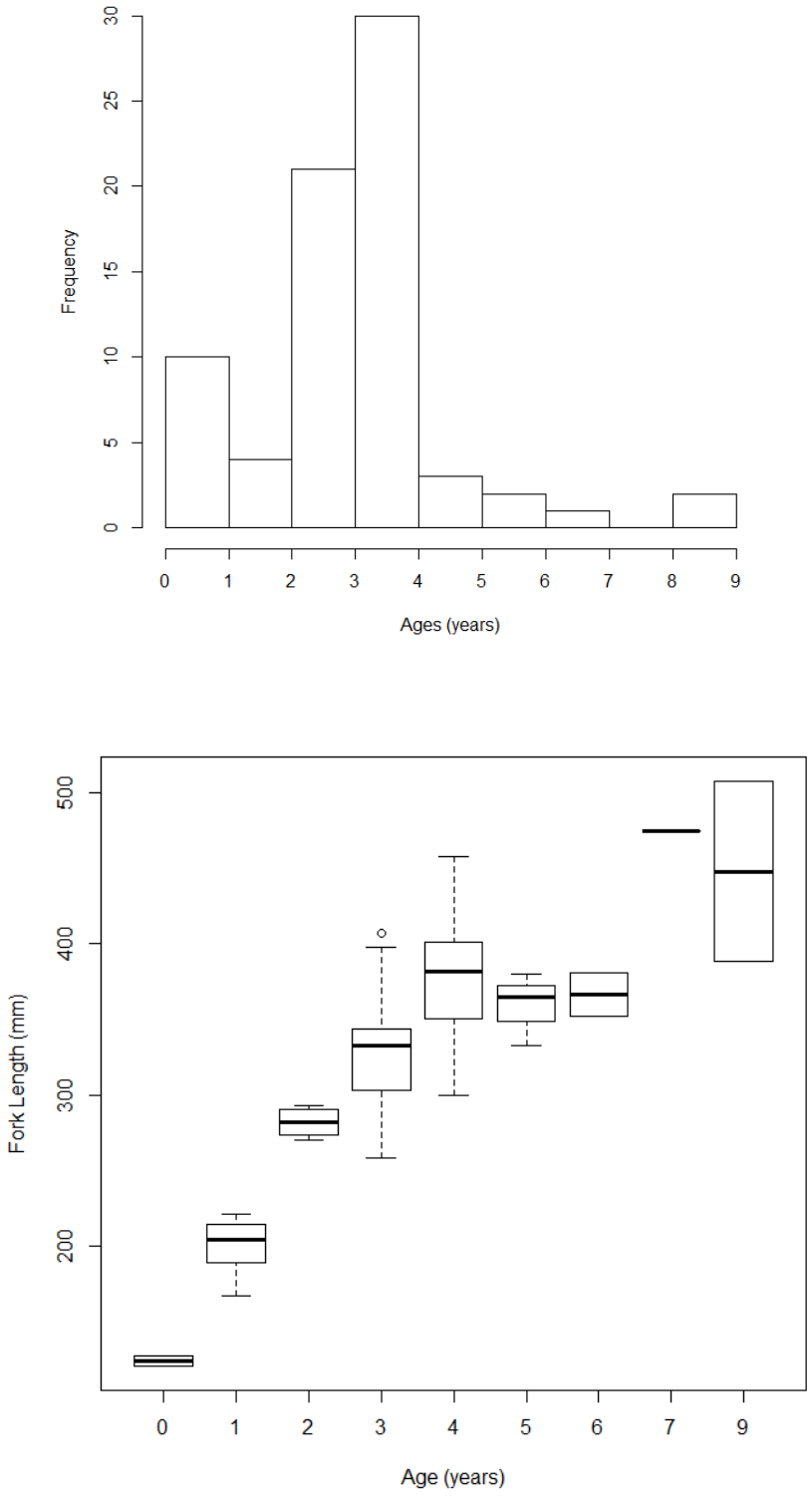


Figure 3. Age distribution of red grouper (n = 73) captured during SEAMAP Groundfish Surveys (top) and length at age information (bottom).

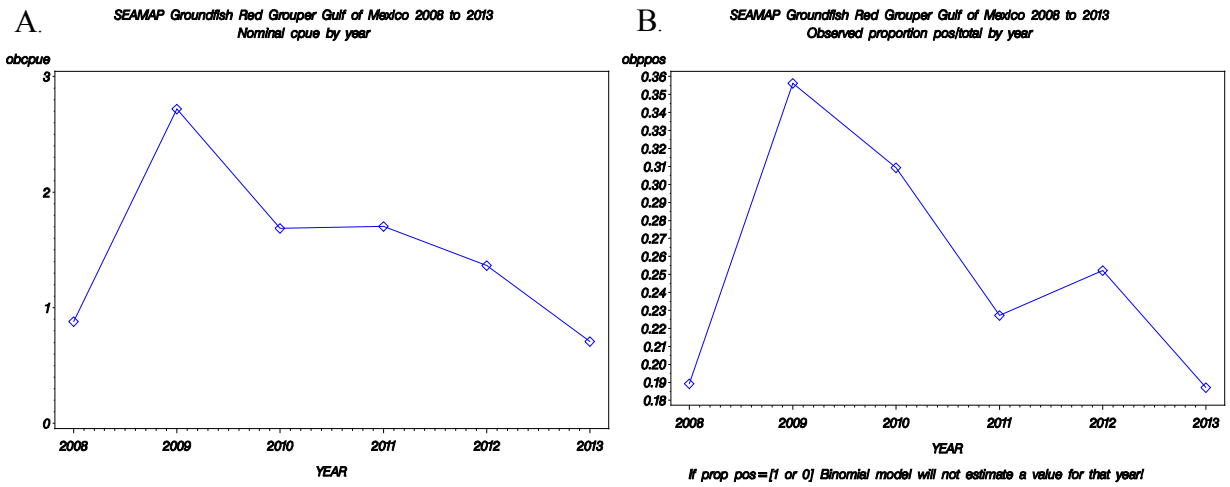


Figure 4. Annual trends for red grouper captured during SEAMAP Groundfish Surveys from 2008 to 2013 in **A.** nominal CPUE and **B.** proportion of positive stations.

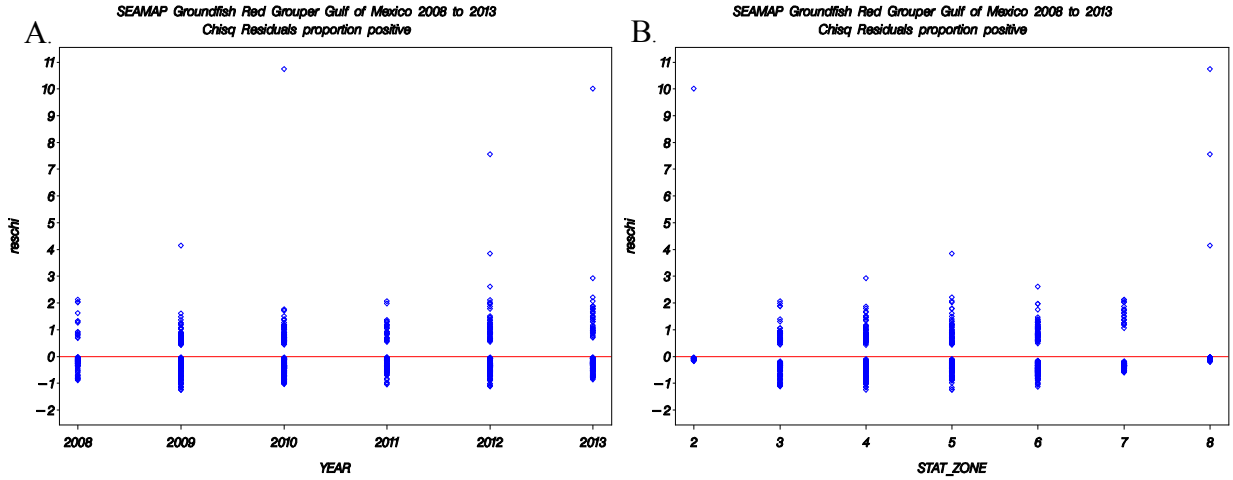


Figure 5. Diagnostic plots for binomial component of the red grouper SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year and **B.** the Chi-Square residuals by shrimp statistical zone.

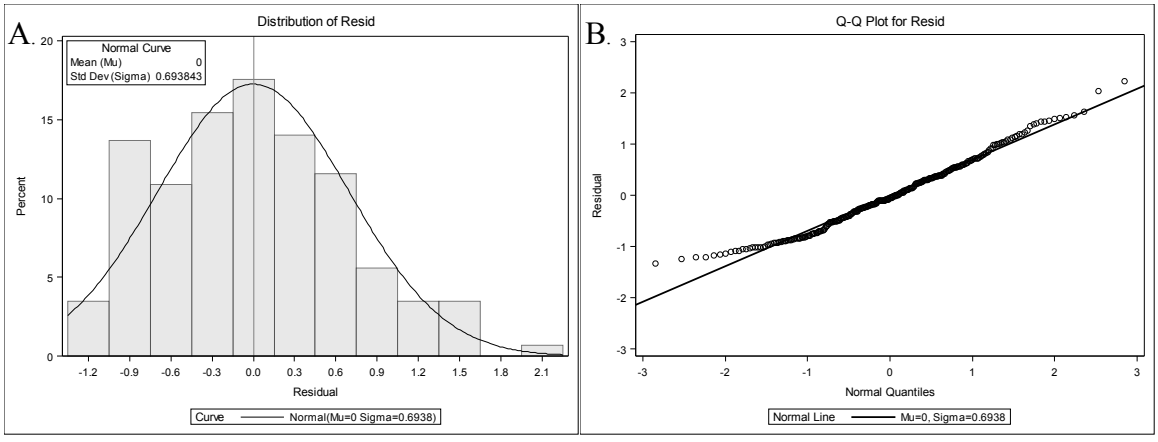


Figure 6. Diagnostic plots for lognormal component of the red grouper SEAMAP Groundfish Survey model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).

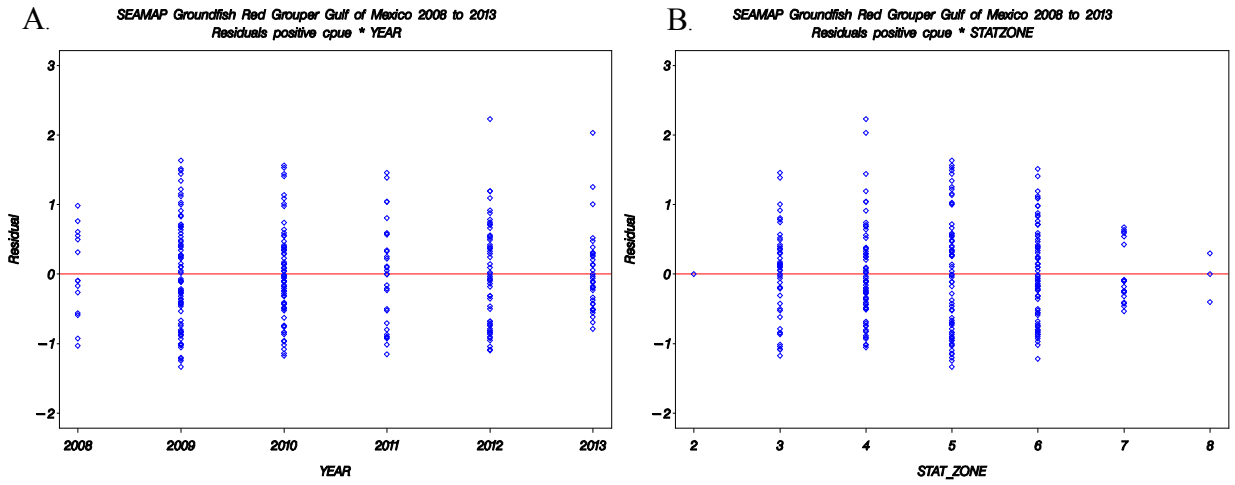


Figure 7. Diagnostic plots for lognormal component of the red grouper SEAMAP Groundfish Survey model: **A.** the Chi-Square residuals by year, and **B.** the Chi-Square residuals by shrimp statistical zone.

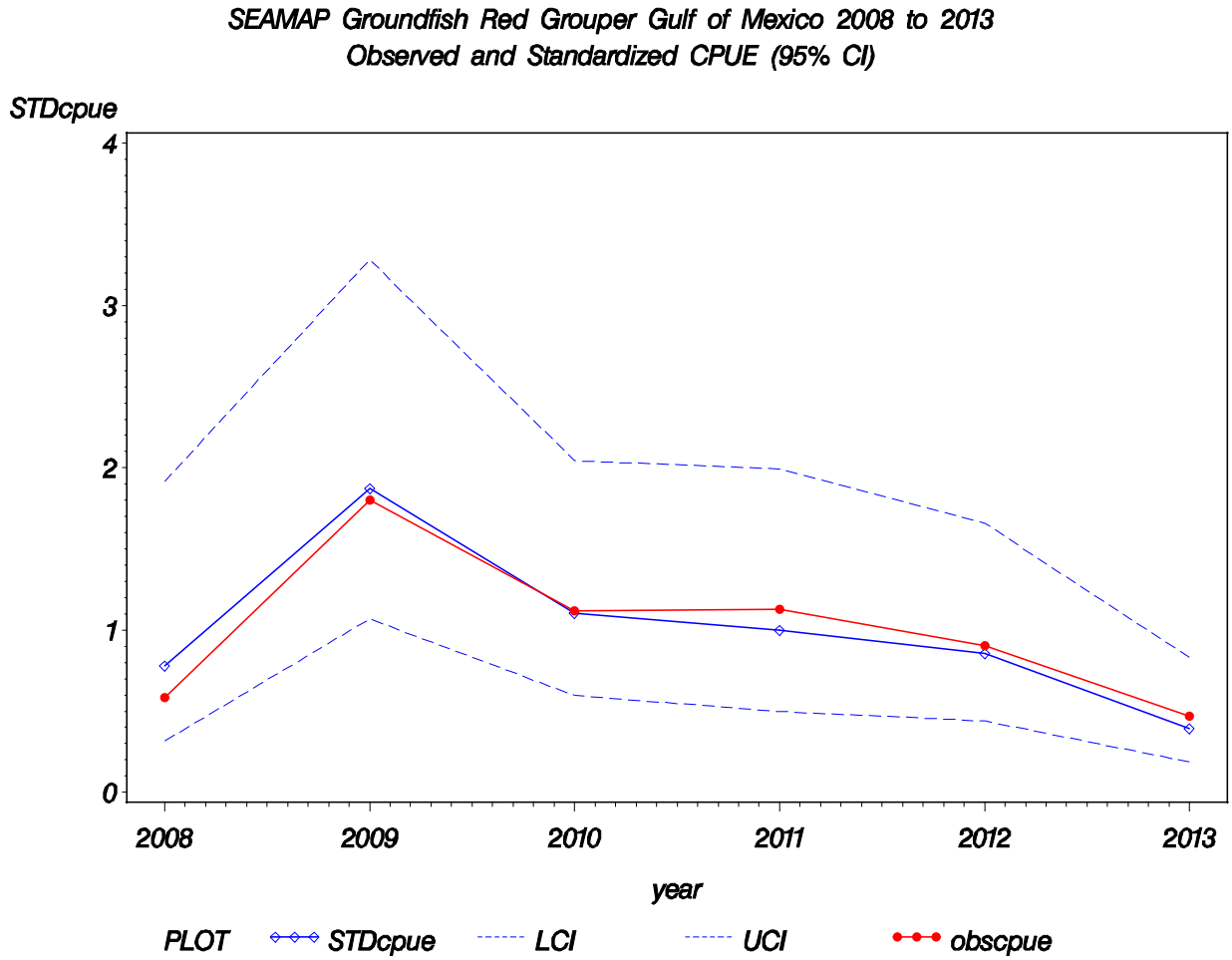


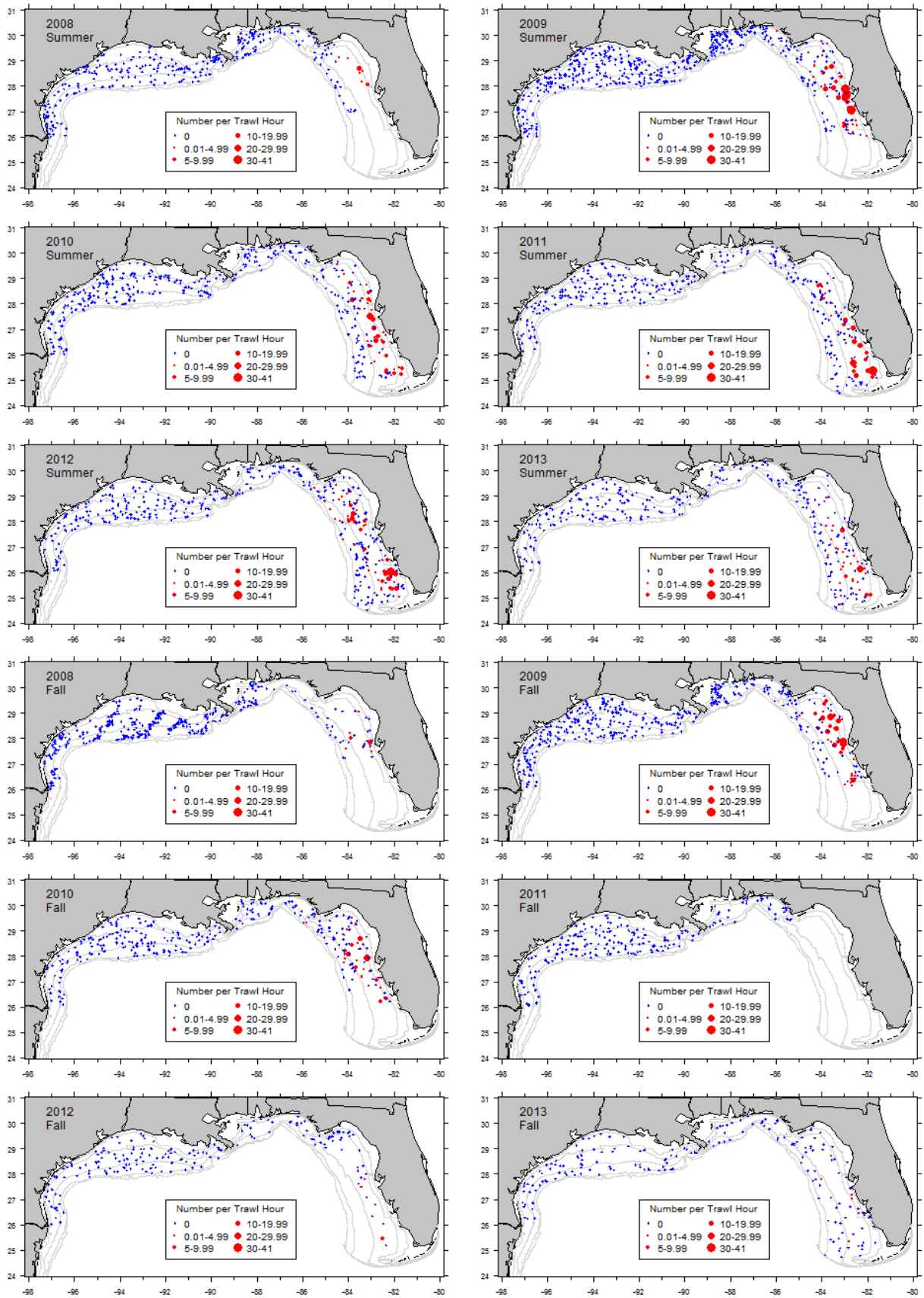
Figure 8. Annual index of abundance for red grouper from the SEAMAP Groundfish Survey from 2008 – 2013.

Appendix

Appendix Table 1. Summary of the factors used in constructing the red grouper abundance index from the SEAMAP groundfish survey data.

Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
YEAR	2008	74	14	0.18919	0.88083
YEAR	2009	219	78	0.35616	2.71960
YEAR	2010	223	69	0.30942	1.68888
YEAR	2011	132	30	0.22727	1.70528
YEAR	2012	222	56	0.25225	1.36631
YEAR	2013	203	38	0.18719	0.70751
SEASON	Fall	360	84	0.23333	1.31071
SEASON	Summer	713	201	0.28191	1.73574
STATZONE	2	36	1	0.02778	0.05556
STATZONE	3	137	46	0.33577	2.18996
STATZONE	4	192	68	0.35417	1.82894
STATZONE	5	205	70	0.34146	2.72267
STATZONE	6	228	77	0.33772	1.91423
STATZONE	7	123	20	0.16260	0.45306
STATZONE	8	152	3	0.01974	0.03905
TOD	D	594	166	0.27946	1.58689
TOD	N	479	119	0.24843	1.60088

Appendix Figure 1. Annual survey effort and catch of red grouper from the SEAMAP groundfish survey during the summer and fall.



Addendum

During the Data Workshop, the Indices Working Group (IWG) raised several concerns and questions about the SEAMAP Groundfish Survey Index. One concern was not directly related to this index in particular, but the section of the code that is used to generate the variance for the index. Based on the recommendation of MCC Statistical Consulting, variance for the new index was calculated using the delta method approximation

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

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 other concerns were with inclusion of the 2008 survey year in the model and inclusion of the Fall survey data. The issue with the 2008 survey year was that the survey just started to expand into the eastern Gulf of Mexico (Appendix Figure 1) and the spatial coverage was extremely limited an area north of Tampa Bay and mostly offshore. The issue with the Fall survey was that the eastern GOM had not been systematically covered since 2008, mainly due to funding and vessel issues. Therefore, the IWG recommended excluding the 2008 survey year and the fall data in the final model.

For the summer SEAMAP abundance index of red grouper, the nominal CPUE and number of stations with a positive catch are presented in Addendum Figure 1. Year, depth and shrimp statistical zone were retained in both the binomial submodel and the lognormal submodel. A summary of the factors used in the analysis is presented in Addendum Table 1. Addendum Table 2 summarizes the final set of variables used in the submodels and their significance. The AIC for the binomial and lognormal submodels were 3375.8 and 433.4, respectively. There was a slight increase in AIC in both submodels, but was deemed acceptable because time of day was not found to be significant. The diagnostic plots for the binomial and lognormal submodels are shown in Addendum Figures 2-4, and indicated the distribution of the residuals is approximately normal. Annual abundance indices are presented in Addendum Table 3 and Addendum Figure 5.

Addendum Table 1. Summary of the factors used in constructing the red grouper abundance index from the SEAMAP Summer Groundfish Survey data.

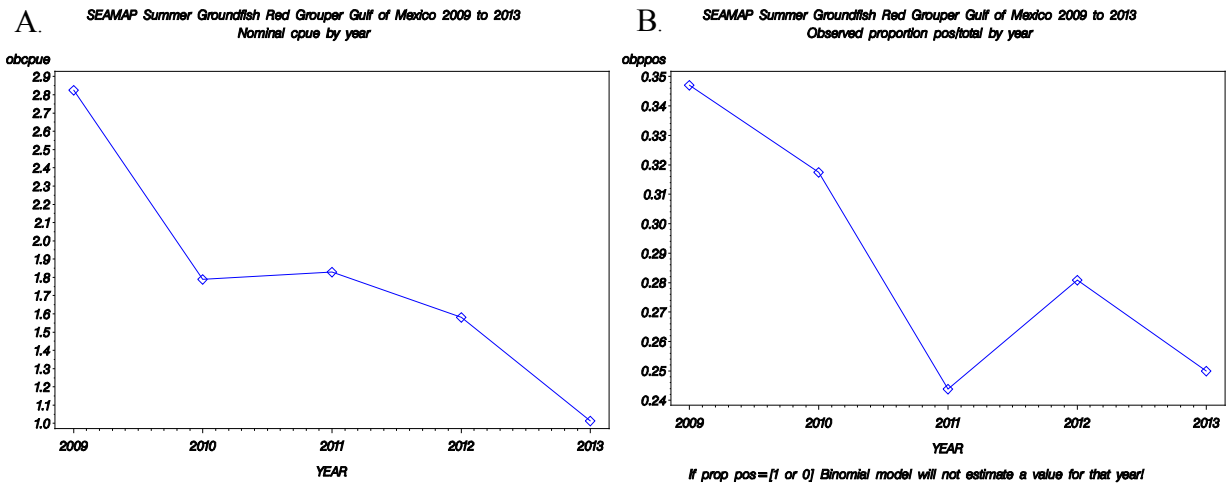
Factor	Level	Number of Observations	Number of Positive Observations	Proportion Positive	Mean CPUE
YEAR	2009	121	42	0.34711	2.82627
YEAR	2010	126	40	0.31746	1.78966
YEAR	2011	123	30	0.24390	1.83006
YEAR	2012	178	50	0.28090	1.58116
YEAR	2013	128	32	0.25000	1.01270
STATZONE	2	32	1	0.03125	0.06250
STATZONE	3	121	44	0.36364	2.38078
STATZONE	4	145	53	0.36552	1.99608
STATZONE	5	117	38	0.32479	3.23573
STATZONE	6	133	47	0.35338	1.65140
STATZONE	7	57	9	0.15789	0.38458
STATZONE	8	71	2	0.02817	0.05634
TOD	D	390	114	0.29231	1.63710
TOD	N	286	80	0.27972	1.97614

Addendum Table 2. Summary of backward selection procedure for building delta-lognormal submodels for red grouper SEAMAP Summer Groundfish Survey index of relative abundance from 2009 to 2013.

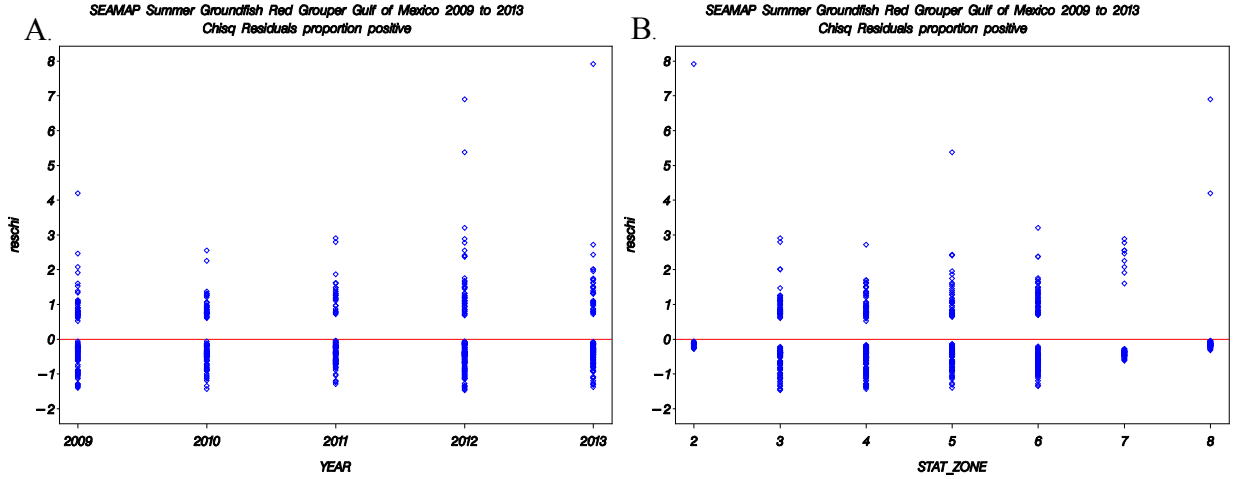
Model Run #1	*Binomial Submodel Type 3 Tests (AIC 3371.2)*						*Lognormal Submodel Type 3 Tests (AIC 432.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	663	3.32	0.83	0.5054	0.5059	4	181	2.10	0.0824
Depth	1	663	61.98	61.98	<.0001	<.0001	1	181	17.86	<.0001
StatZone	6	663	48.88	8.15	<.0001	<.0001	6	181	4.07	0.0008
Time of Day	1	663	0.75	0.75	0.3855	0.3858	1	181	3.36	0.0685
Model Run #2	*Binomial Submodel Type 3 Tests (AIC 3375.8)*						*Lognormal Submodel Type 3 Tests (AIC 433.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
Year	4	664	3.32	0.83	0.5059	0.5064	4	182	1.98	0.1001
Depth	1	664	60.87	60.87	<.0001	<.0001	1	182	18.60	<.0001
StatZone	6	664	48.02	8.00	<.0001	<.0001	6	182	4.02	0.0008
Time of Day				Dropped					Dropped	

Addendum Table 3. Indices of red grouper abundance developed using the delta-lognormal model for SEAMAP Summer Groundfish Survey from 2009-2013. The nominal frequency of occurrence, the number of samples (*N*), the DL Index (number per trawl-hour), the DL indices scaled to a mean of one for the time series, the coefficient of variation on the mean (CV), and lower and upper confidence limits (LCL and UCL) for the scaled index are listed.

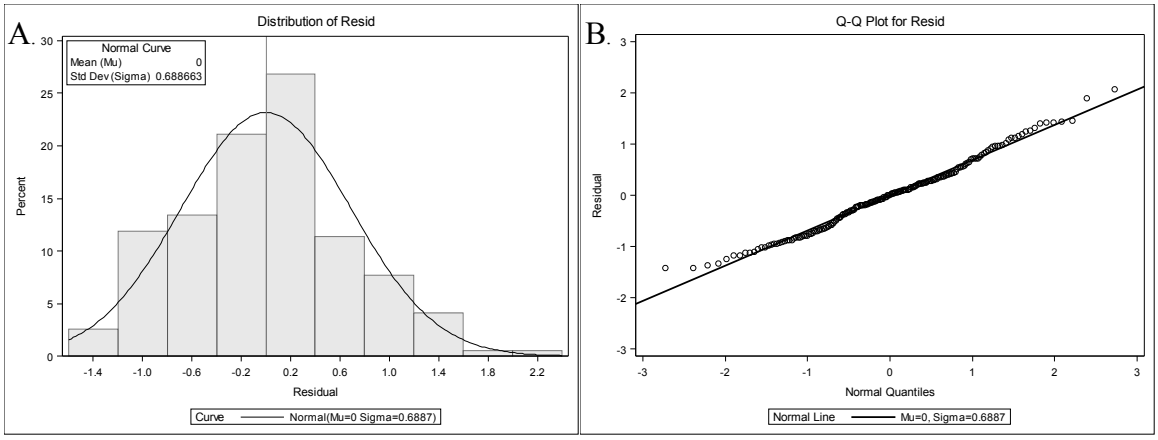
Survey Year	Nominal Frequency	N	Lo Index	Scaled Lo Index	CV	LCL	UCL
2009	0.34711	121	1.18369	1.47025	0.26932	0.86605	2.49597
2010	0.31746	126	0.76371	0.94861	0.27511	0.55268	1.62818
2011	0.24390	123	0.75150	0.93343	0.29512	0.52369	1.66375
2012	0.28090	178	0.76632	0.95184	0.25543	0.57570	1.57374
2013	0.25000	128	0.56024	0.69587	0.28890	0.39500	1.22589



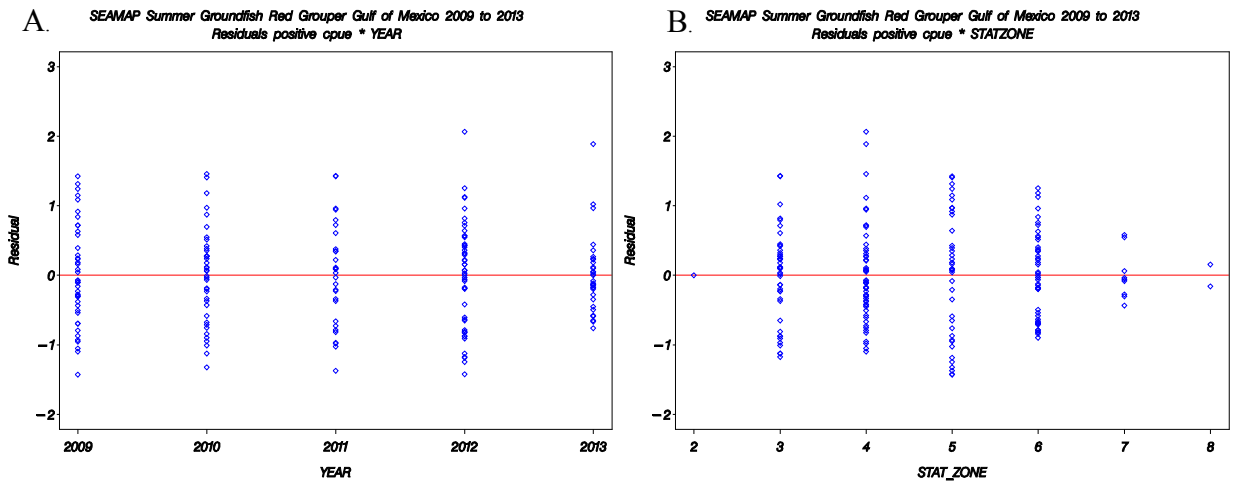
Addendum Figure 1. Annual trends for red grouper captured during SEAMAP Summer Groundfish Surveys from 2009 to 2013 in **A.** nominal CPUE and **B.** proportion of positive stations.



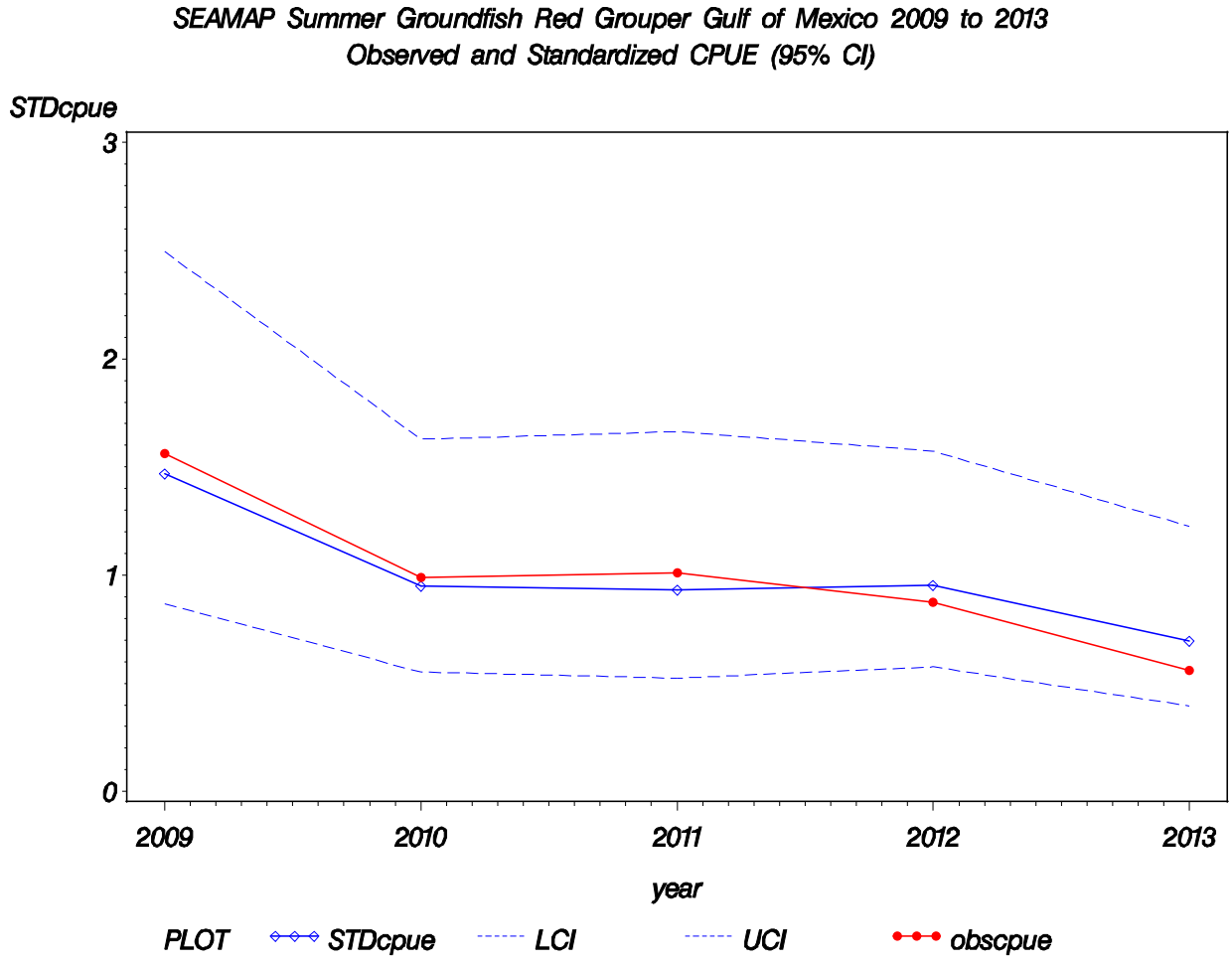
Addendum Figure 2. Diagnostic plots for binomial component of the red grouper SEAMAP Summer Groundfish Survey model: **A.** the Chi-Square residuals by year and **B.** the Chi-Square residuals by shrimp statistical zone.



Addendum Figure 3. Diagnostic plots for lognormal component of the red grouper SEAMAP Summer Groundfish Survey model: **A.** the frequency distribution of log (CPUE) on positive stations and **B.** the cumulative normalized residuals (QQ plot).



Addendum Figure 4. Diagnostic plots for lognormal component of the red grouper SEAMAP Summer Groundfish Survey model: **A.** the Chi-Square residuals by year, and **B.** the Chi-Square residuals by shrimp statistical zone.



Addendum Figure 5. Annual index of abundance for red grouper from the SEAMAP Summer Groundfish Survey from 2009 – 2013.