Abundance Indices of Red Snapper Collected in NMFS Bottom Longline Surveys in the northern Gulf of Mexico

G. Walter Ingram, Jr. and Adam G. Pollack

SEDAR31-DW19

9 August 2012

Abundance Indices of Red Snapper Collected in NMFS Bottom Longline Surveys in the northern Gulf of Mexico

G. Walter Ingram, Jr. and Adam G. Pollack
NOAA Fisheries, Southeast Fisheries Science Center, Mississippi Laboratories, Pascagoula, MS

Introduction

The Southeast Fisheries Science Center (SEFSC) Mississippi Laboratories has conducted standardized bottom longline surveys in the Gulf of Mexico, Caribbean, and Western North Atlantic since 1995. The objective of these surveys is to provide fisheries independent data for stock assessment purposes for as many species as possible. These surveys are conducted annually in U.S. waters of the Gulf of Mexico (GOM) and/or the Atlantic Ocean (Table 1), and they provide an important source of fisheries independent information on large coastal sharks, snappers and groupers from the GOM and Atlantic. The evolution of these surveys has been the subject of many documents [e.g., Ingram *et al*. 2005 (LCS05/06-DW-27)] and was not described again in this document. In 2011, an Expanded Stock Assessment Survey was conducted where high levels of survey effort were maintained from April through October. For this analysis, only data collected during the same time period as the annual survey were used to increase sample size. Results from analyses of data collected on red snapper during this survey are presented below in order to aid in the current assessment of this stock in the GOM.

Methods and Results

For the SEDAR 31, we used the time series of data between 1996 and 2011 to develop abundance indices for red snapper for the GOM. Due to the use of J-type hooks and the shallow depths primarily surveyed in early years, few snapper were captured. With the change to circle-hooks, grouper and snapper catches increased by an order of magnitude (LCS05/06-DW-27). Also, the survey coverage area varied during the time series due to weather or mechanical problems, the positions of all stations and the catch rates of stations where red snapper were collected were plotted by year and all years combined (Figures 1-2). Therefore, with these data concerns, a model-based approach was used to develop this index of abundance.

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; 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) $$\ln(\mathbf{c}) = \mathbf{X\beta} + \boldsymbol{\varepsilon}$$

and

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

We used the GLIMMIX and MIXED procedures in SAS (v. 9.1, 2004) to develop the binomial and lognormal submodels, respectively. Similar covariates were tested for inclusion for both submodels: water depth [three depth categories: shallow (9 – 55 m), medium (55 – 183 m), and deep (183 – 366 m)], survey region [two regions in the GOM: Eastern Gulf (east of 89.15° west longitude) and Western Gulf (west of 89.15° west longitude)] and year. A backward selection procedure was used to determine which variables were to be included into each submodel based on type 3 analyses with a level of significance for inclusion of $\alpha = 0.05$. If year was not significant then it was forced into each submodel in order to estimate least-squares means for each year, which are predicted annual population margins (i.e., they estimate the marginal annual means as if over a balanced population).

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

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

The backward selection procedure used to develop the delta-lognormal model is summarized in Table 2 for red snapper for the entire US GOM between 9 and 366 m, in Table 3 for those from the Western GOM, and Table 4 from those from the Eastern GOM. For red snapper Gulfwide all variables for both submodels were significant and retained. For the Western GOM, the hook effect was dropped from the binomial submodel based on type 3 analyses, and with the variable removal there was a corresponding decrease in AIC (Table 2). For the lognormal submodel for nonzero catch of red snapper in the Western GOM, the water depth variable was dropped from the model; the year variable was not significant (Table 2). However, due to the increase of the AIC at the removal of the water depth variable, this marginally significant variable was retained in the final model (Table 2). For the Eastern GOM, the hook effect was dropped from the lognormal submodel due to a lack of model convergence, since there were no red snapper captured on J-hooks in the Eastern GOM (Table 3). All other variables from both submodel were

subsequently removed based on type 3 analyses for both submodels until only year was left. Initially there was an increase in the AIC value with the removal of the water depth variable from the binomial submodel. However, due to its high insignificance, it was left as removed (Table 3). This resulted in basically a nominal model for the Eastern GOM.

Figures 3, 6, and 9 summarize indices of red snapper collected during bottom longline surveys in the US GOM, the Western GOM, and the Eastern GOM, respectively, developed using a delta-lognormal model. Figures 4, 5, 7, 8, 10, and 11 provide diagnostics for each of the submodels in the index development. The QQplot sub-figure in each of the aforementioned figures indicates the approximately normal distribution of the residuals of corresponding submodels.

Finally, we constructed an age-frequency histogram for red snapper (Figure 12) collected during this survey in the GOM.

Literature Cited

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

LO, N. C. H., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49: 2515-1526.

Table 1. NMFS MS Laboratory longline projects, 1995 - 2009. Shaded rows indicate cruises from which data was used in this document. For surveys that occurred in both the Atlantic and Gulf of Mexico within a single survey, only data from the Gulf was used.

Survey	Date	Location	Depth range (m)	Effort (# sets)	Random station selection description.
OT-95-04 (218)	7/23 - 8/17/95	GOM[1]	18 m - 73 m	82	Stations depth stratified and equally allocated within statistical zones; depth strata 18 m - 37 m, 37 m - 55 m, 55 m - 73 m; J hooks.
RS-95-03 (2)	8/10 - 8/24/95	Atlantic[2]	18 m - 73 m	45	Stations depth stratified and equally allocated within statistical zones; depth strata 18 m - 37 m, 37 m - 55 m, 55 m - 73 m; J hooks.
OT-96-04 (222)	7/31 - 9/13/96	GOM and Atlantic	18 m - 73 m	151	Stations depth stratified and equally allocated within statistical zones; depth strata 18 m - 37 m, 37 m - 55 m, 55 m - 73 m; J hooks.
OT-97-04 (227)	7/25 - 9/24/97	Mexican GOM, GOM and Atlantic	9 m - 55 m	259	Stations not depth stratified but equally allocated within 60 linear n. mile zones or statistical zones; J hooks.
OT-98-02 (231)	7/24 - 9/22/98	Mexican GOM, Cuba [3], GOM	9 m - 413 m	216	Stations not depth stratified but equally allocated within 60 linear n. mile zones or statistical zones; J hooks.
OT-99-02 (233)	2/16 - 3/2/99	Atlantic	9 m - 55 m	29	Stations not depth stratified but equally allocated within statistical zones; J hooks.
FE-99-10 SEF	5/6 - 5/19/99	GOM	64 m - 146 m	60	Station coordinates by random longitude and random depth and equally allocated within 10 linear n. mile contiguous sampling blocks; circle hooks.
CARETTA 99-01	8/4 - 9/28/99	GOM	9 m - 55 m	161	Proportional allocation based on continental shelf width within statistical zones; sampling density experiment; hook comparison experiment with 75% J hooks, 25% circle hooks.
GU-00-03 (8)	6/6 - 6/19/00	GOM	64 m - 146 m	59	Station coordinates by random longitude and random depth and equally allocated within 20 linear n. mile contiguous sampling blocks; hook comparison experiment with 75% circle hooks, 25% J hooks.
OT-00-04 (241)	8/3 - 8/28/00	GOM	9 m - 183 m	137	Proportional allocation based on continental shelf width within statistical zones; sampling density experiment; hook comparison experiment with 75% J hooks, 25% circle hooks.
FE-00-12 (2)	9/6 - 10/16/00	Atlantic	9 m - 183 m	105	Proportional allocation based on continental shelf width within statistical zones; sampling density experiment; hook comparison experiment with 75% J hooks, 25% circle hooks.
OT-00-08 (244)	12/6 - 12/12/00	GOM	55 m - 366 m	41	Station coordinates by random longitude and random depth and equally allocated within 10 linear n. mile contiguous sampling blocks; stations depth stratified with 4 stations each block 55 m - 183 m, 2 stations each block 183 m - 366 m; hook comparison experiment with 75% circle hooks, 25% J hooks.
ONJUKU-01	6/1 - 6/20/01	Mexican GOM[4]	9 m - 50 m	38	Proportional allocation based on continental shelf width within 60 linear n. mile sampling zones; circle hooks, Atlantic bonito for bait.
OT-01-04 (247)	7/31 - 9/30/01	GOM	9 m - 366 m	277	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
ONJUKU-01	6/28 - 7/5/02	Mexican GOM[4]	18 m - 217 m	30	Proportional allocation based on continental shelf width within 60 linear n. mile sampling zones; circle hooks, Atlantic bonito for bait
OT-02-04 (251)	7/31 - 9/21/02	GOM and Atlantic	9 m - 366 m	212	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-03-04 (255)	7/29 - 9/29/03	GOM	9 m - 366 m	280	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
GANDY 72-043	07/25 - 08/28/04	Atlantic	8 m – 34 m	40	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-04-04 (260)	7/31 - 9/29/04	GOM	9 m - 366 m	232	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
GANDY 72-044	10/06 - 10/23/04	GOM	7 m – 92 m	17	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-05-04 (266)	8/5 - 8/25/05	GOM and Atlantic	9 m - 366 m	74	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-06-04 (272)	7/29 - 9/24/06	GOM and Atlantic	9 m - 366 m	208	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-07-04 (277)	8/10 - 8/24/07	GOM	9 m - 366 m	156	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-08-04 (283)	8/2 - 9/29/08	GOM and Atlantic	9 m - 366 m	145	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-09-04 (288)	7/30 - 9/29/09	GOM and Atlantic	9 m - 366 m	211	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-09-04 (288)	8/2 - 9/29/10	GOM and Atlantic	9 m - 366 m	172	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
OT-09-04 (288)	7/28 - 9/28/11	GOM and Atlantic	9 m - 366 m	171	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.
Expanded Stock Assessment - Multiple Vessels	4/8 – 10/25/11	GOM	9 m - 366 m	1020	Proportional allocation based on continental shelf width within statistical zones; depth stratified, 50% allocation 9 m - 55 m, 40% allocation 55 m - 183 m, 10% allocation 183 m - 366 m; circle hooks.

Figure 1. Distribution of catch and effort for the bottom longline survey from 1996 - 2011. Blue symbols are indicative of effort, and red symbols of catch rate (# per 100 hookhours).

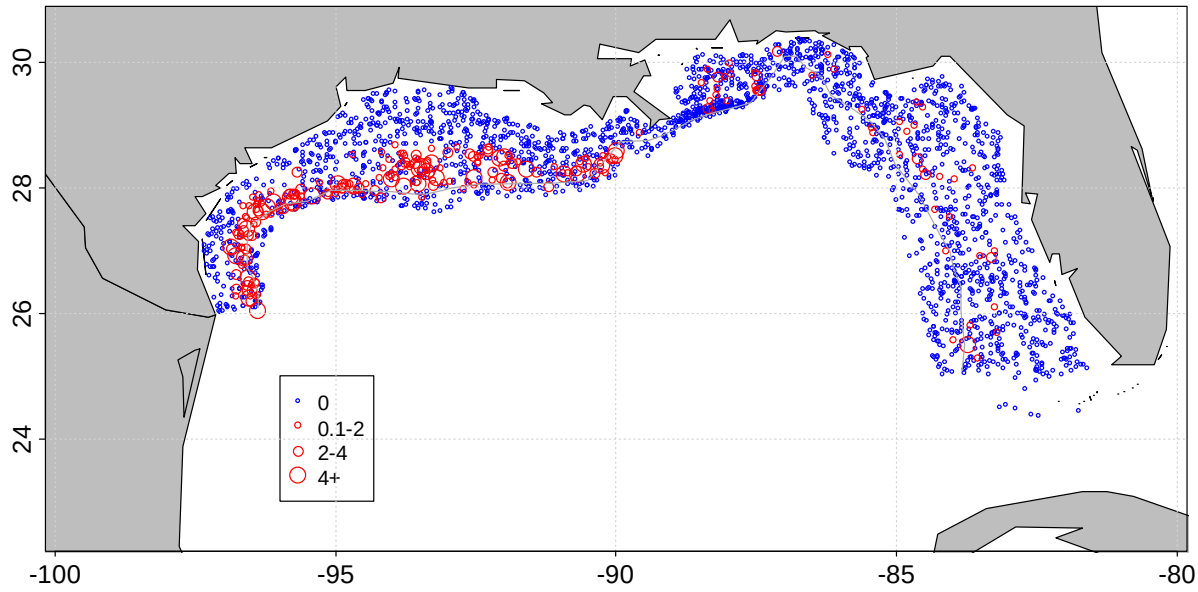
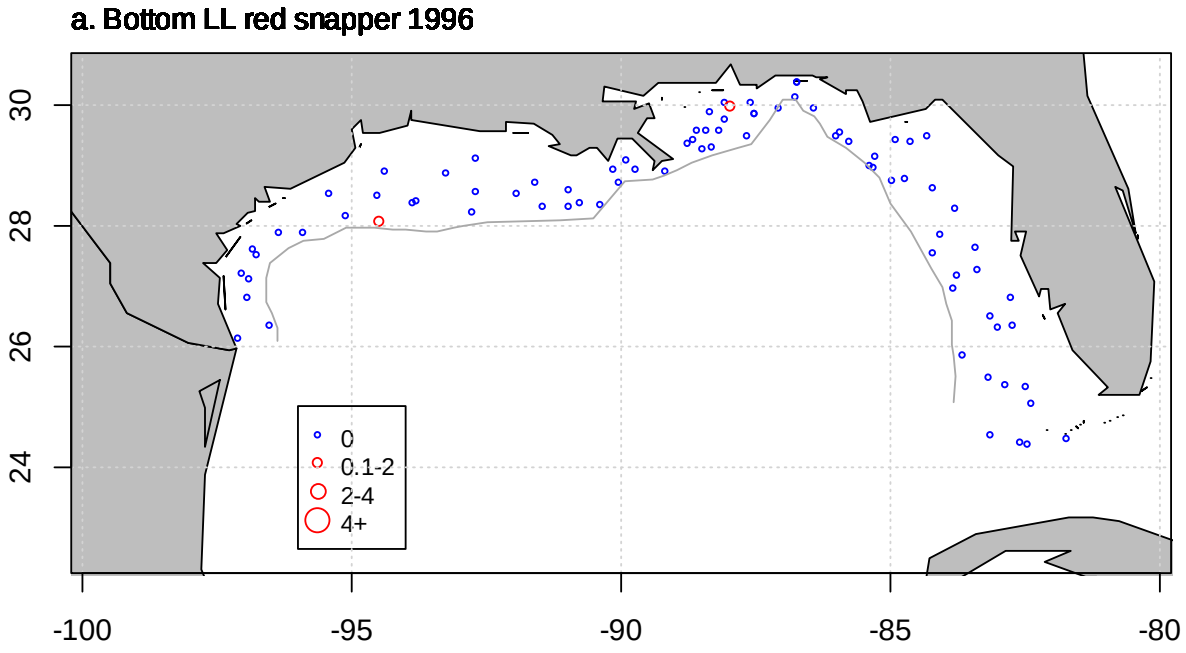
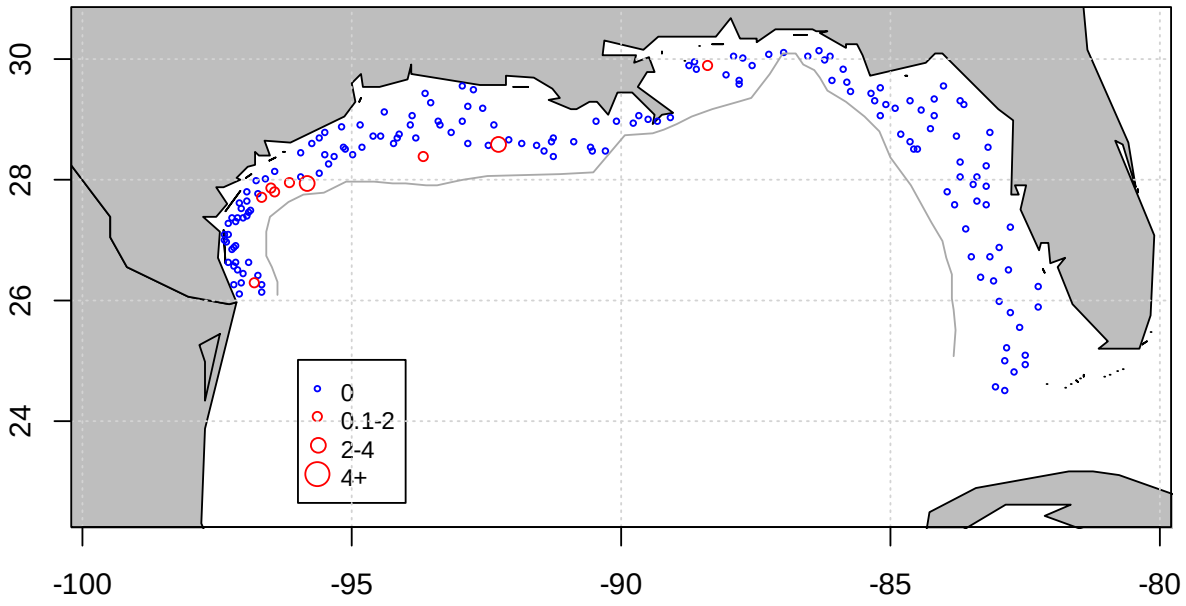


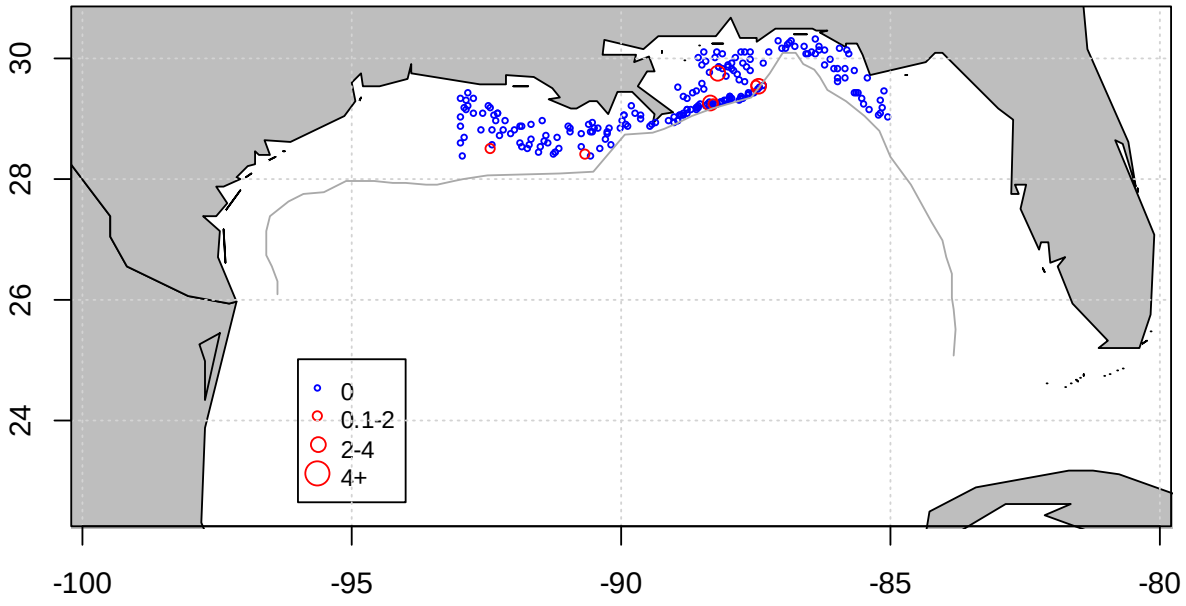
Figure 2. Annual distribution of catch and effort for the bottom longline survey from 1996 - 2011. Blue symbols are indicative of effort, and red symbols of catch rate (# per 100 hookhours).



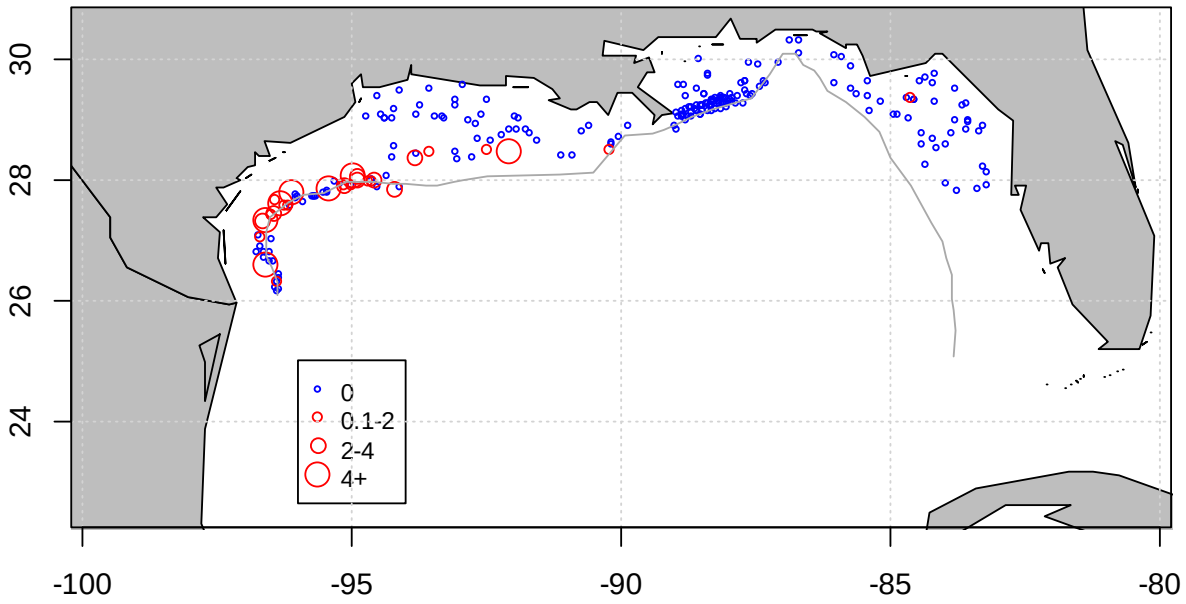
b. Bottom LL red snapper 1997



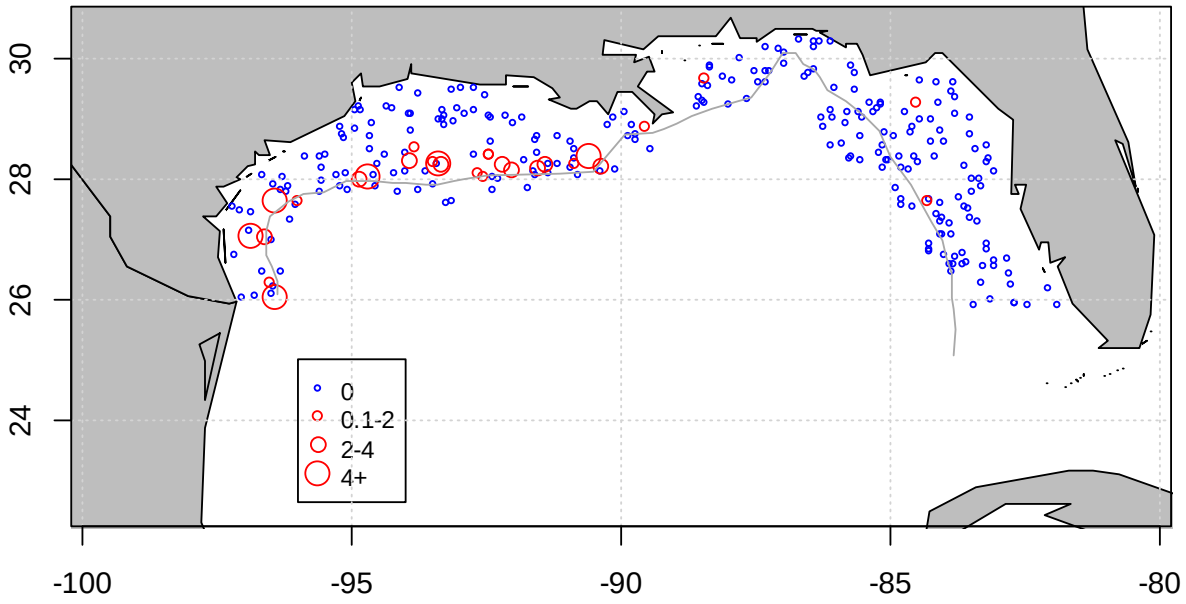
c. Bottom LL red snapper 1999



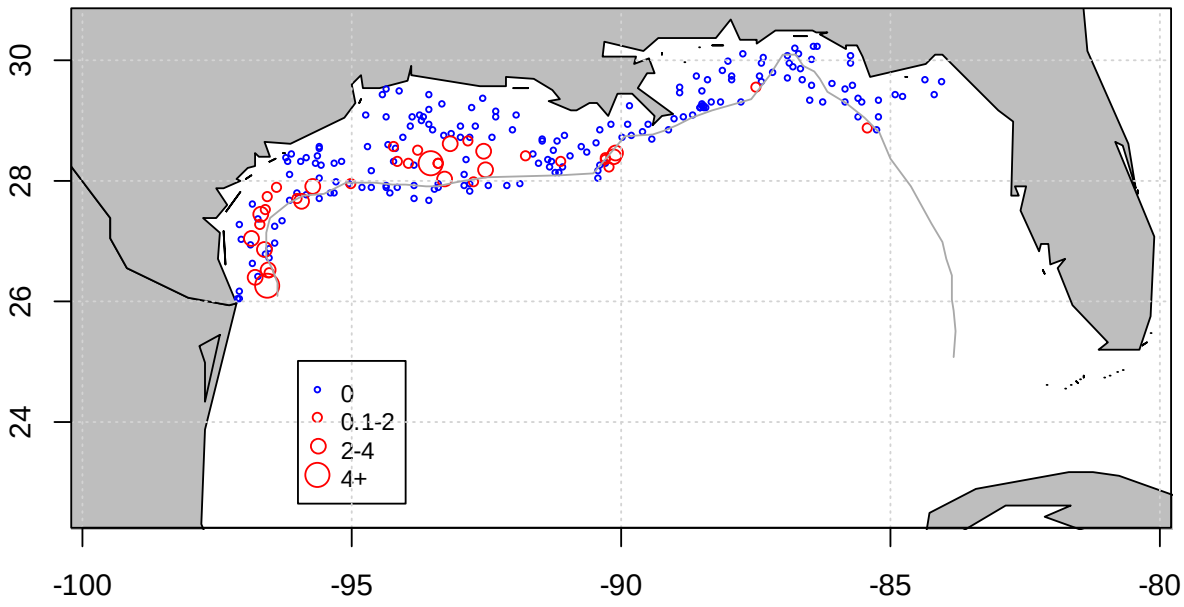
d. Bottom LL red snapper 2000



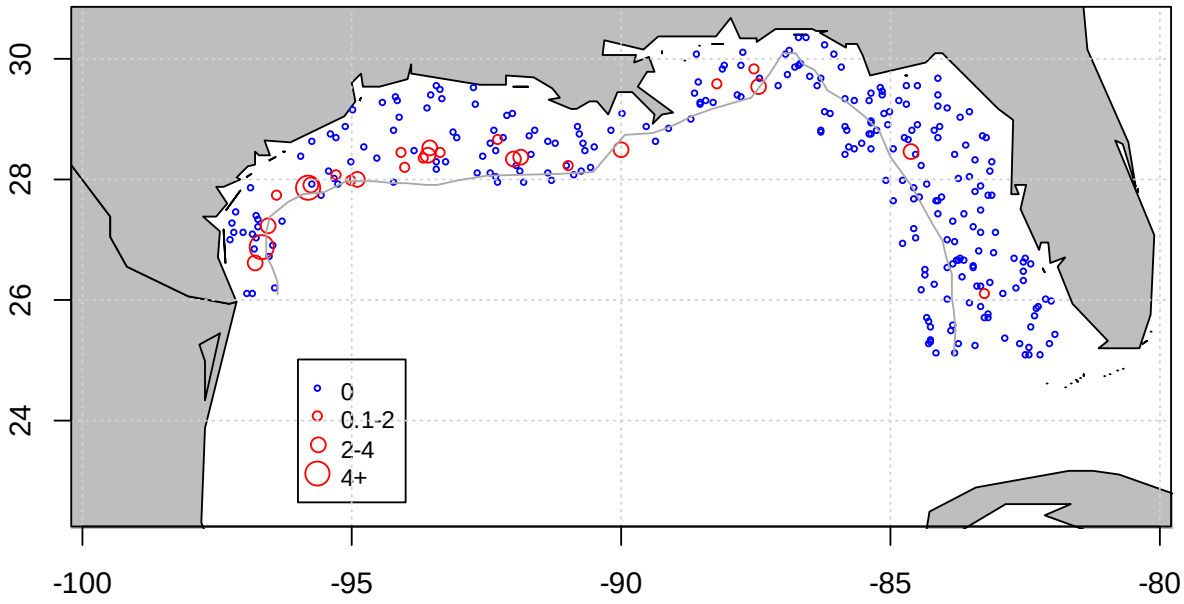
e. Bottom LL red snapper 2001



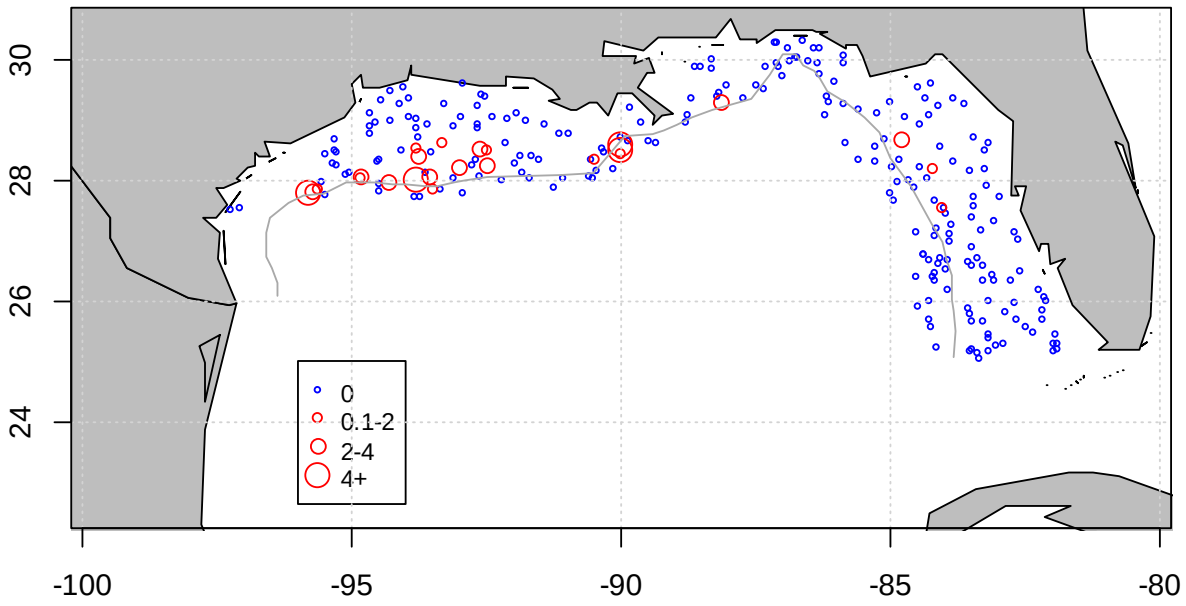
f. Bottom LL red snapper 2002



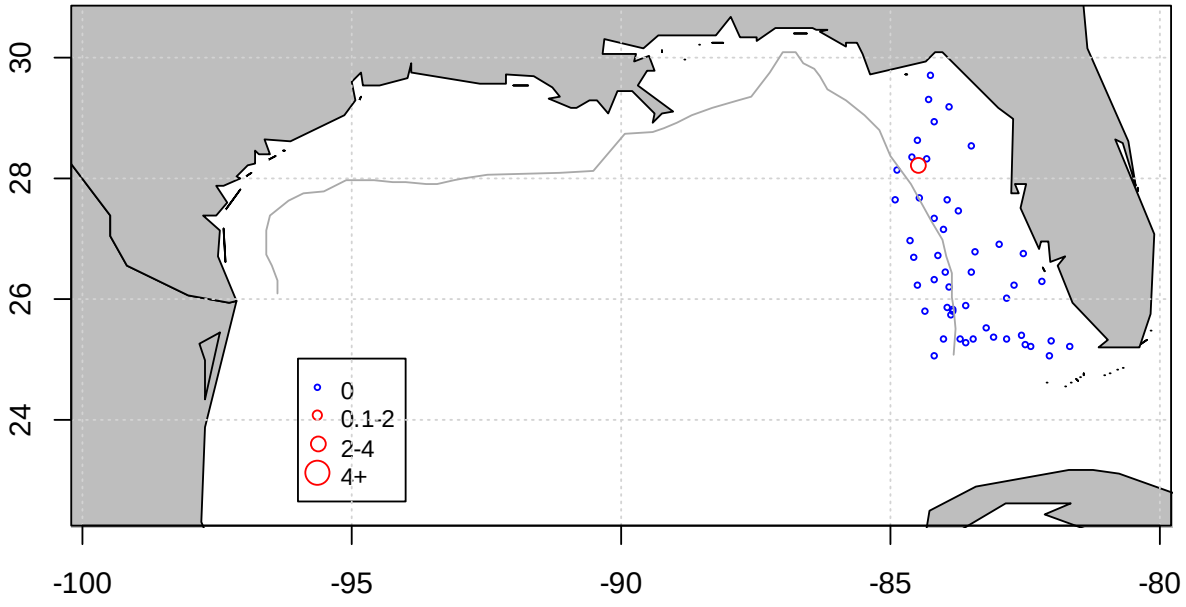
g. Bottom LL red snapper 2003



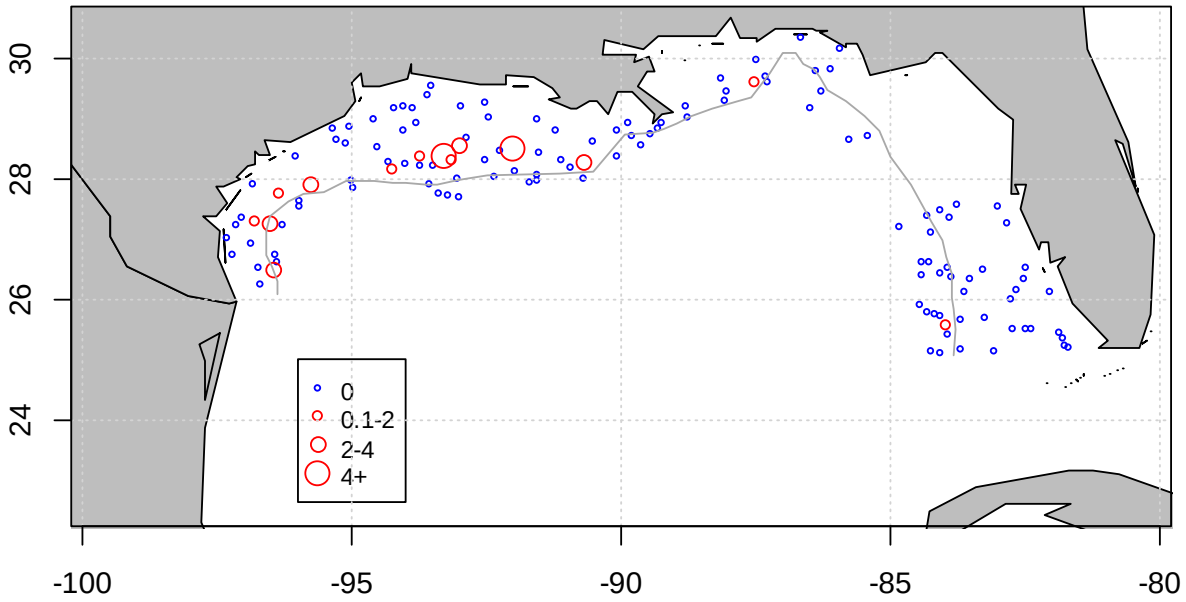
h. Bottom LL red snapper 2004



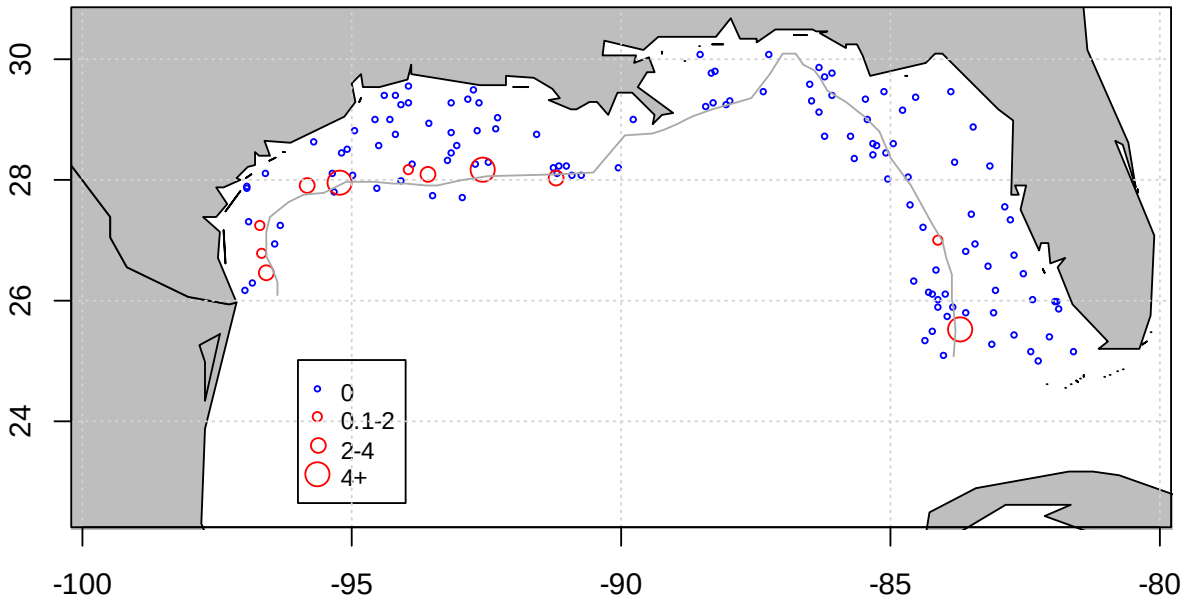
i. Bottom LL red snapper 2005



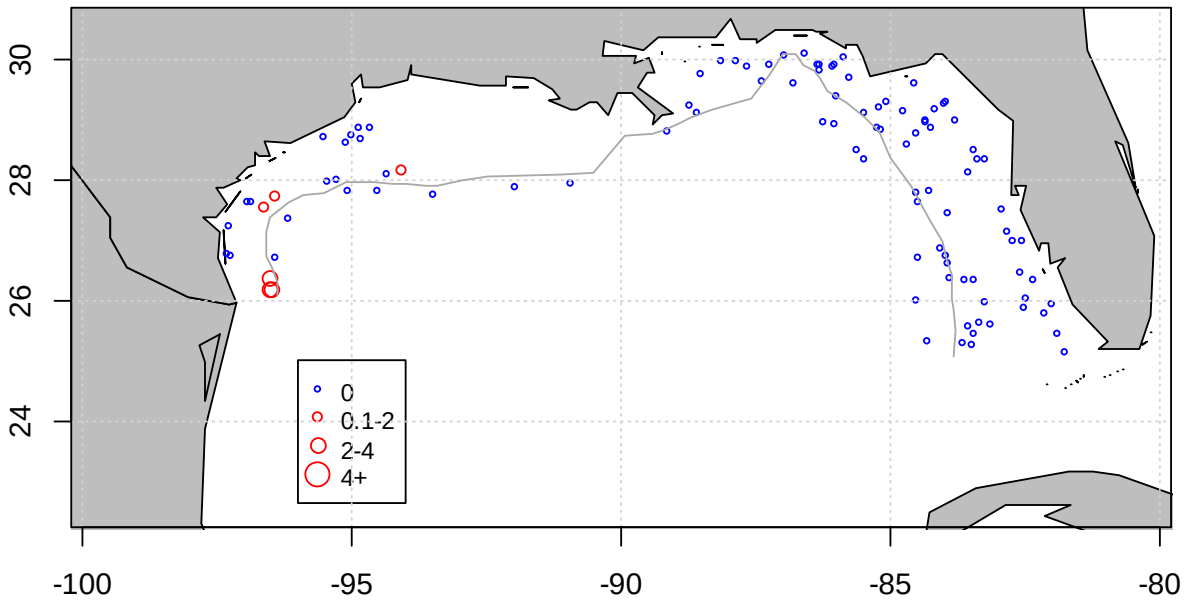
j. Bottom LL red snapper 2006



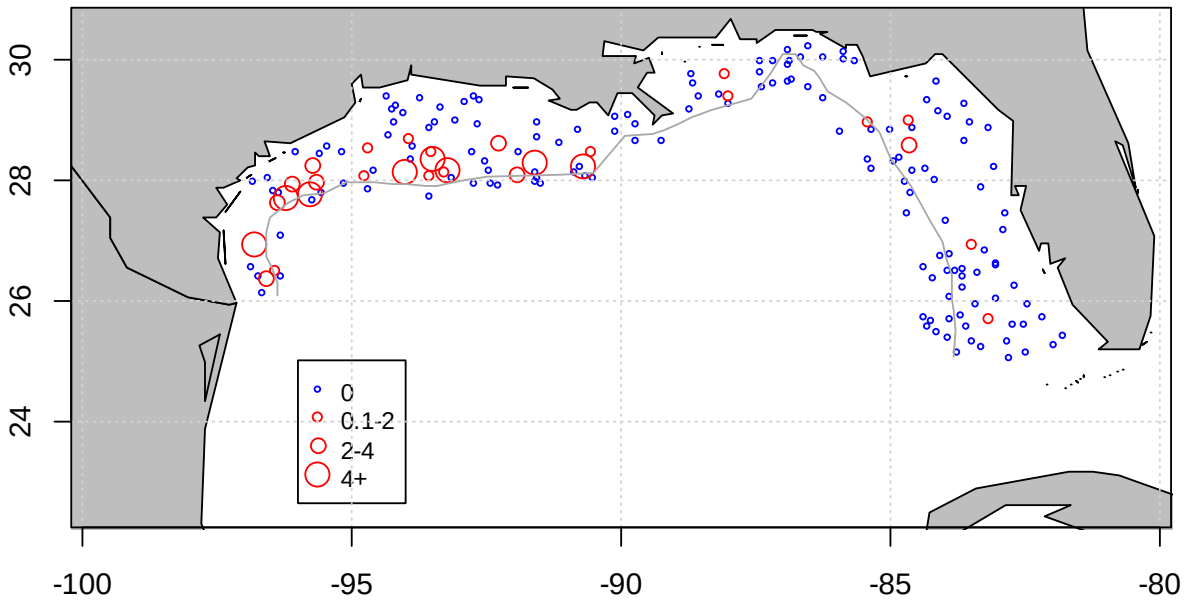
k. Bottom LL red snapper 2007



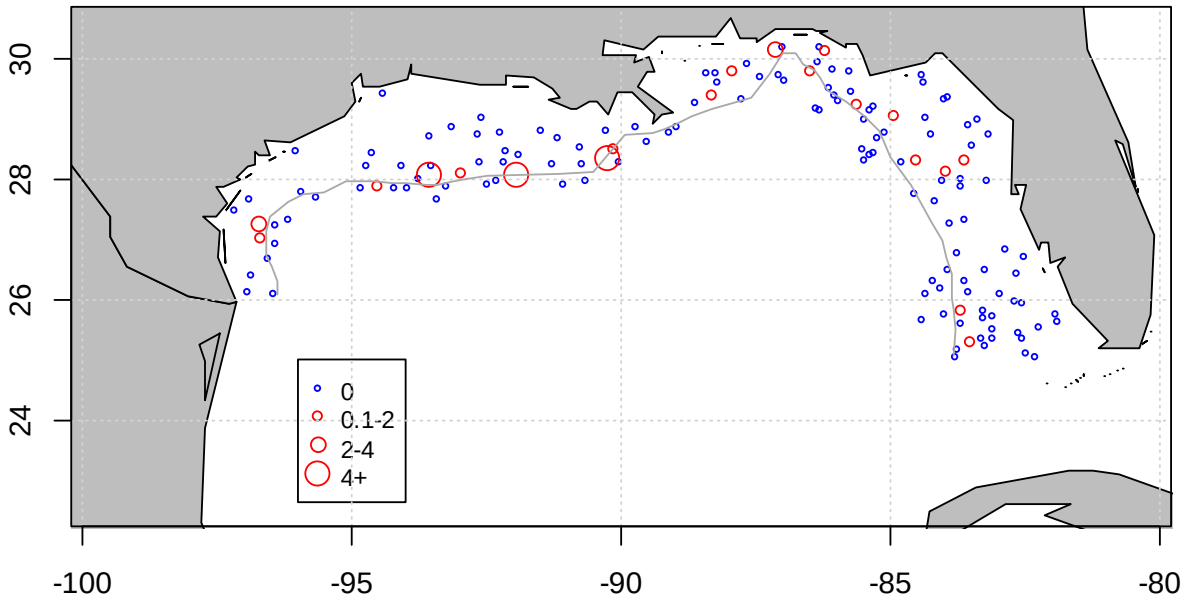
l. Bottom LL red snapper 2008



m. Bottom LL red snapper 2009



n. Bottom LL red snapper 2010



o. Bottom LL red snapper 2011

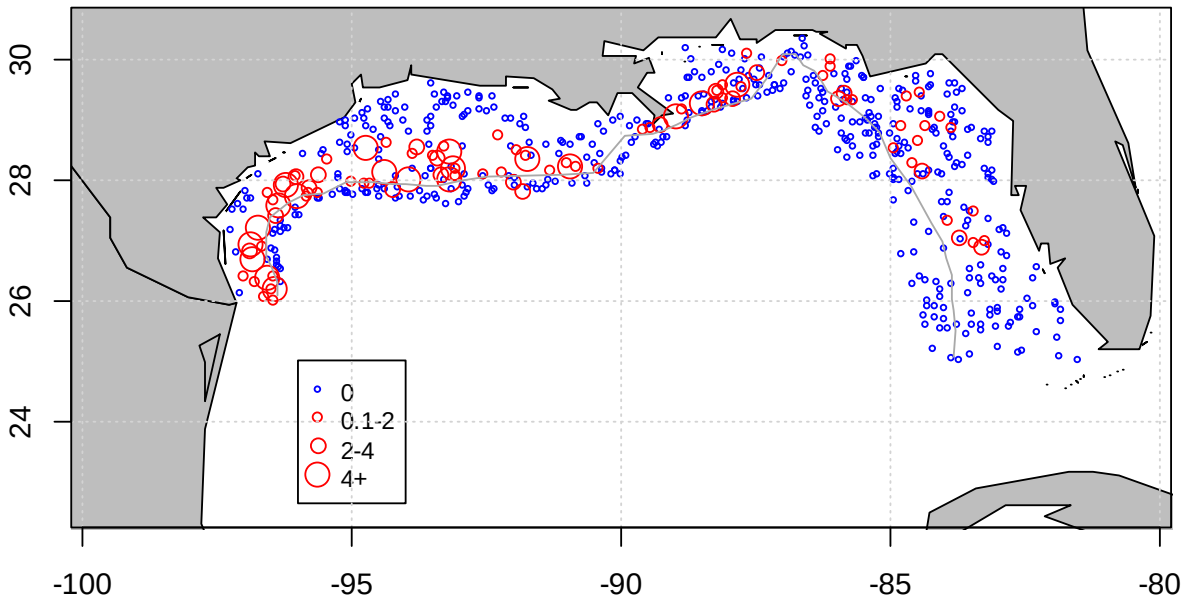
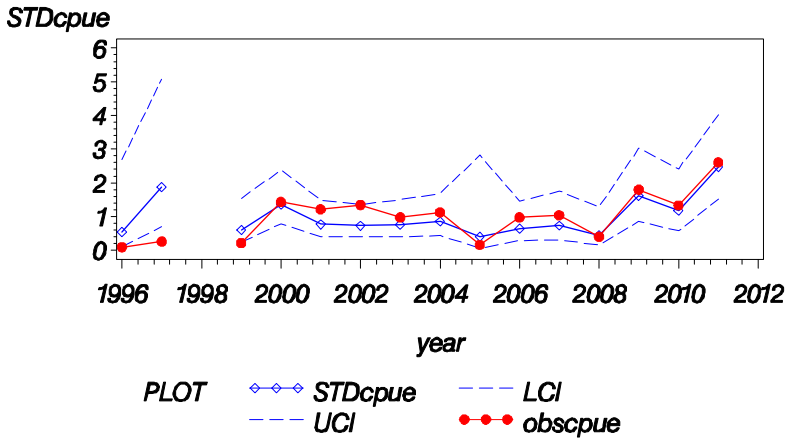


Table 2. Backward selection procedure for building delta-lognormal submodels for red snapper collected during Bottom Longline Surveys in the Gulf of Mexico.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC = 15872.0)*						*Lognormal Submodel Type 3 Tests (AIC = 762.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	14	2749	37.85	2.70	0.0005	0.0006	14	322	1.75	0.0446
hook	1	2749	5.35	5.35	0.0207	0.0208	1	322	5.25	0.0225
region	1	2749	130.40	130.40	<.0001	<.0001	1	322	21.09	<.0001
depthzone	1	2749	83.54	83.54	<.0001	<.0001	1	322	4.99	0.0261

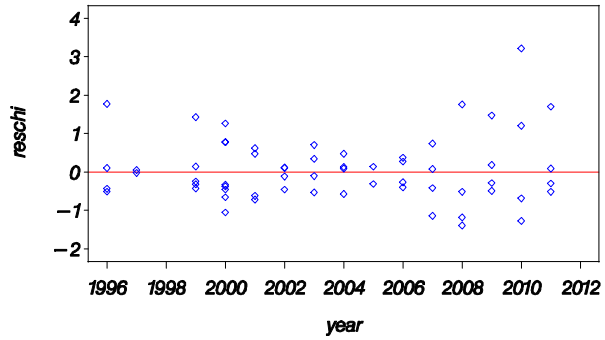
Figure 3. Gulfwide abundance indices for red snapper collected during Bottom Longline Surveys. STDcpue is the index scaled to a mean of one over the time series. Obscpue is the average nominal CPUE, and LCI and UCI are 95% confidence limits. In the table below, the *frequency* listed is nominal frequency, *N* is the number of bottom longline stations, *Index* is the abundance index in CPUE units, *Scaled Index* is the index scaled to a mean of one over the time series, *CV* is the coefficient of variation on the index value, and *LCL* and *UCL* are 95% confidence limits.



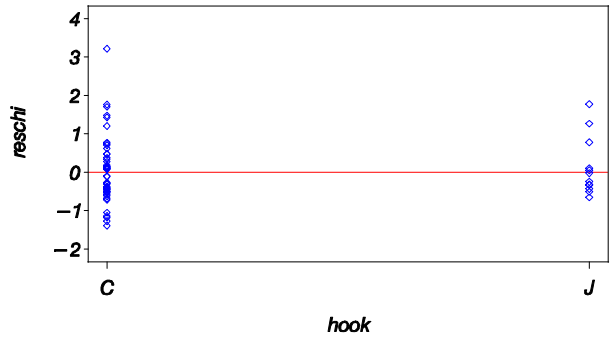
Survey Year	*Frequency*	*N*	*Index*	*Scaled Index*	*CV*	*LCL*	*UCL*
1996	0.02381	84	0.09231	0.54490	0.94485	0.11029	2.69225
1997	0.05325	169	0.31867	1.88113	0.52884	0.69677	5.07869
1999	0.03167	221	0.10300	0.60800	0.48988	0.24047	1.53724
2000	0.12236	237	0.23096	1.36341	0.28445	0.78044	2.38182
2001	0.10145	276	0.13043	0.76994	0.33794	0.39887	1.48624
2002	0.16742	221	0.12392	0.73149	0.31646	0.39434	1.35691
2003	0.08929	280	0.13011	0.76805	0.34461	0.39303	1.50092
2004	0.09677	247	0.14475	0.85449	0.34875	0.43395	1.68259
2005	0.02000	50	0.06879	0.40610	1.24975	0.05837	2.82546
2006	0.10370	135	0.10959	0.64692	0.42163	0.28807	1.45277
2007	0.08271	133	0.12452	0.73505	0.45800	0.30710	1.75934
2008	0.05825	103	0.07449	0.43972	0.57687	0.15053	1.28445
2009	0.16667	180	0.27254	1.60884	0.32404	0.85517	3.02671
2010	0.13514	148	0.19907	1.17515	0.37178	0.57223	2.41336
2011	0.16248	597	0.41788	2.46680	0.24719	1.51565	4.01484

Figure 4. Diagnostic residual plots of the binomial submodel for red snapper collected during Bottom Longline Surveys in the Gulf of Mexico.

a. Chi-square residuals by year.

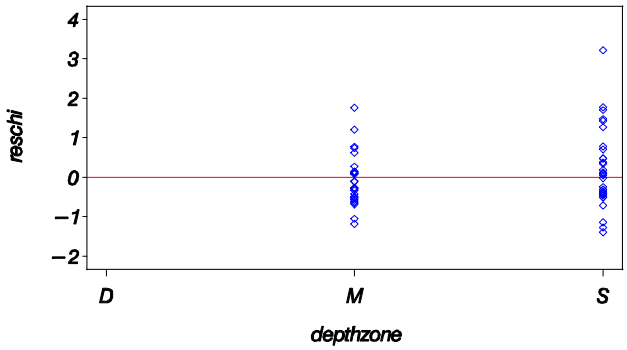


b. Chi-square residuals by hook type.



c. Chi-square residuals by region.

d. Chi-square residuals by depthzone.



e. QQplot of chi-square residuals.

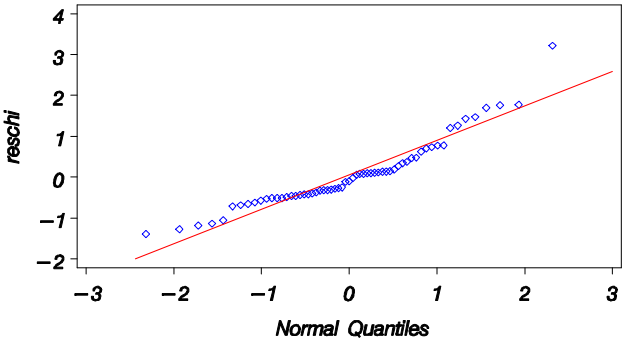
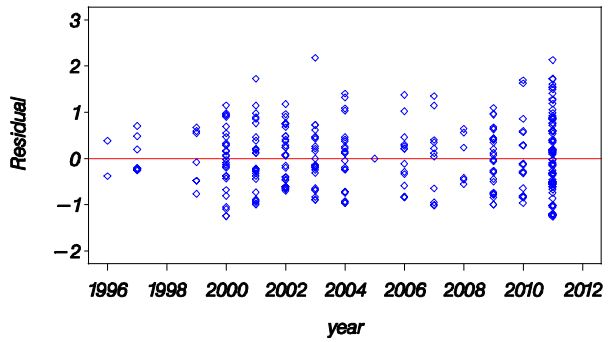
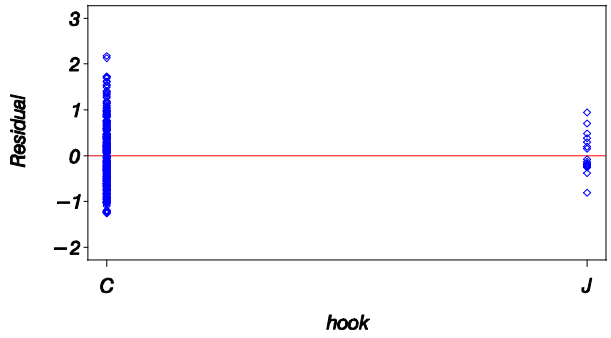


Figure 5. Diagnostic residual plots of the lognormal submodel for red snapper collected during Bottom Longline Surveys in the Gulf of Mexico.

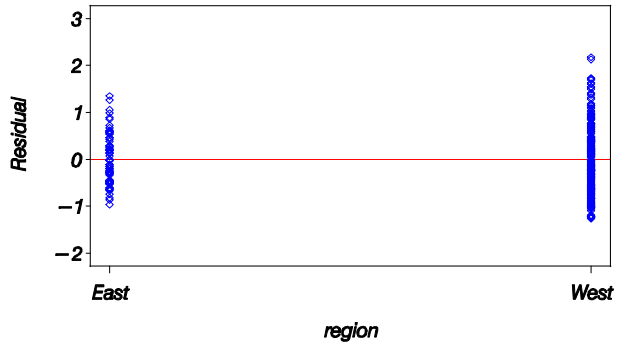
a. Chi-square residuals by year.



b. Chi-square residuals by hook type.



c. Chi-square residuals by region.



d. Chi-square residuals by depthzone.

e. QQplot of chi-square residuals.

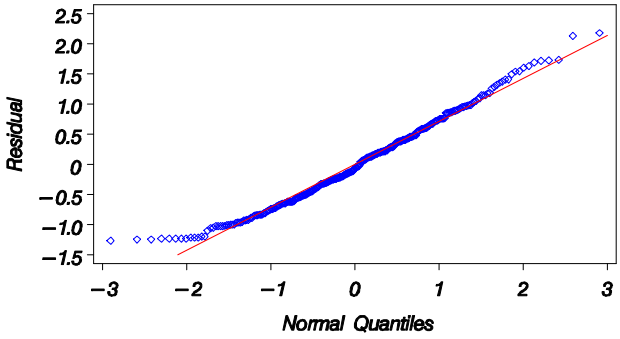
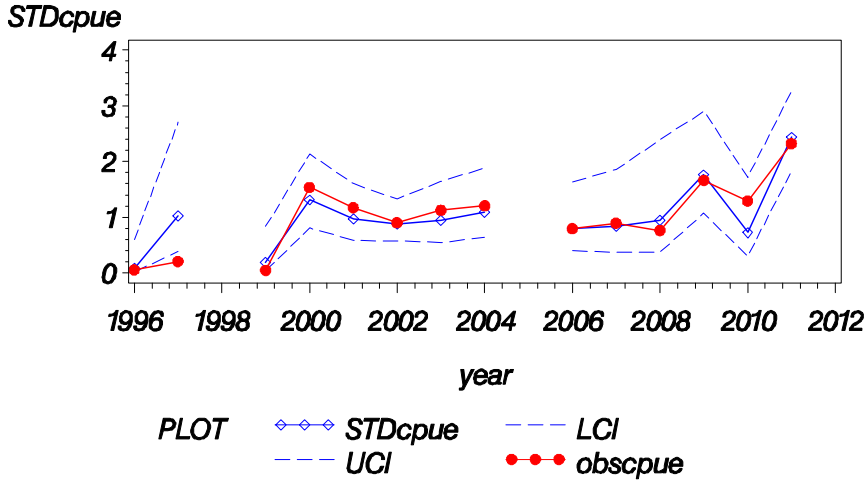


Table 3. Backward selection procedure for building delta-lognormal submodels for red snapper collected during Bottom Longline Surveys in the Western Gulf of Mexico. ** indicates the model chosen for the index.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC = 6322.6)*						*Lognormal Submodel Type 3 Tests (AIC = 625.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	13	1250	27.76	2.14	0.0098	0.0104	13	251	1.45	0.1357
hook	1	1250	2.53	2.53	0.1118	0.1121	1	251	3.57	0.0598
depthzone	1	1250	112.51	112.51	<.0001	<.0001	1	251	3.17	0.0762
Model Run #2	*Binomial Submodel Type 3 Tests (AIC = 6304.2)*						*Lognormal Submodel Type 3 Tests (AIC = 626.4)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	13	1251	32.67	2.51	0.0019	0.0021	13	252	1.37	0.1761
hook	dropped						1	252	5.11	0.0246
depthzone	1	1251	118.97	118.97	<.0001	<.0001	dropped			
Model Run #3*	*Binomial Submodel Type 3 Tests (AIC = 6304.2)*						*Lognormal Submodel Type 3 Tests (AIC = 625.7)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	13	1251	32.67	2.51	0.0019	0.0021	13	251	1.45	0.1357
hook	dropped						1	252	5.11	0.0246
depthzone	1	1251	118.97	118.97	<.0001	<.0001	1	251	3.17	0.0762

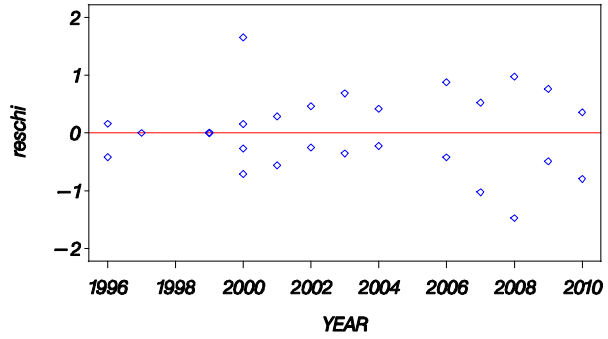
Figure 6. West Gulf abundance indices for red snapper collected during Bottom Longline Surveys. STDcpue is the index scaled to a mean of one over the time series. Obscpue is the average nominal CPUE, and LCI and UCI are 95% confidence limits. In the table below, the *frequency* listed is nominal frequency, *N* is the number of bottom longline stations, *Index* is the abundance index in CPUE units, *Scaled Index* is the index scaled to a mean of one over the time series, *CV* is the coefficient of variation on the index value, and *LCL* and *UCL* are 95% confidence limits.



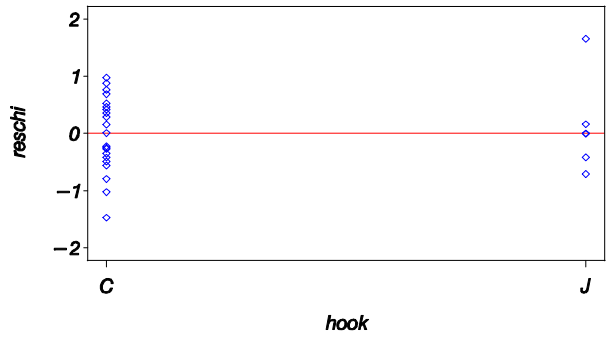
Survey Year	Frequency	N	Index	Scaled Index	CV	LCL	UCL
1996	0.03125	32	0.04902	0.08784	1.23704	0.01279	0.60334
1997	0.08247	97	0.57197	1.02482	0.51420	0.38899	2.69992
1999	0.02500	80	0.10384	0.18605	0.86676	0.04163	0.83144
2000	0.25926	108	0.73217	1.31184	0.24629	0.80741	2.13141
2001	0.18519	135	0.54078	0.96893	0.25505	0.58646	1.60084
2002	0.22152	158	0.48713	0.87281	0.21362	0.57205	1.33169
2003	0.19048	105	0.52859	0.94709	0.28012	0.54659	1.64105
2004	0.19608	102	0.61010	1.09313	0.27837	0.63297	1.88783
2006	0.15584	77	0.44889	0.80429	0.36356	0.39753	1.62723
2007	0.14754	61	0.46597	0.83488	0.41770	0.37437	1.86188
2008	0.22222	27	0.52562	0.94176	0.49310	0.37045	2.39418
2009	0.27059	85	0.98404	1.76314	0.25283	1.07171	2.90065
2010	0.15094	53	0.40471	0.72512	0.45197	0.30615	1.71749
2011	0.24823	282	1.36087	2.43831	0.14600	1.82365	3.26014

Figure 7. Diagnostic residual plots of the binomial submodel for red snapper collected during Bottom Longline Surveys in the Western Gulf of Mexico.

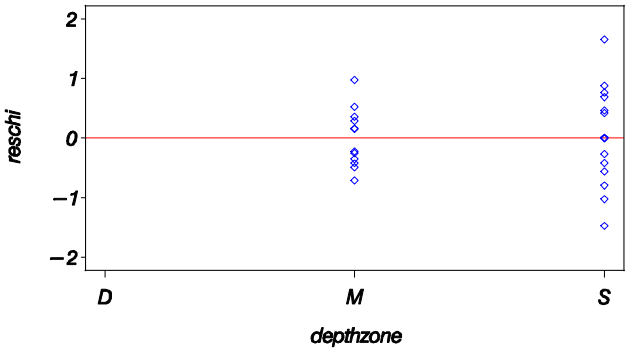
a. Chi-square residuals by year.



b. Chi-square residuals by hook type.



c. Chi-square residuals by depthzone.



d. QQplot of chi-square residuals.

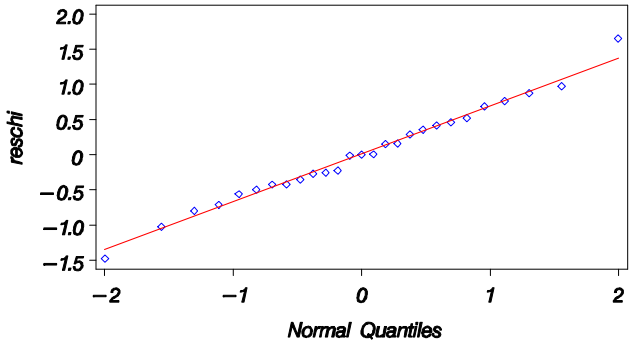
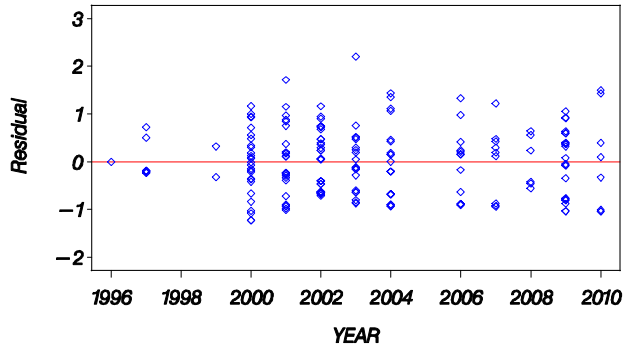
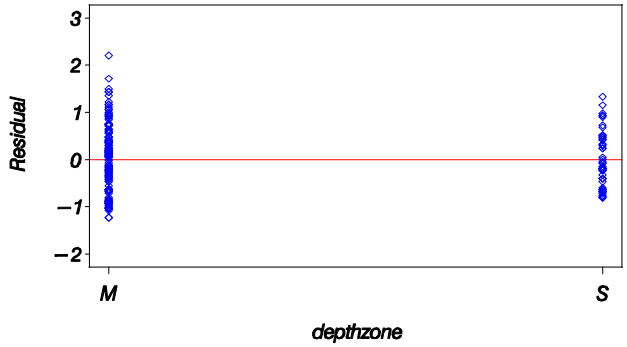


Figure 8. Diagnostic residual plots of the lognormal submodel for red snapper collected during Bottom Longline Surveys in the Western Gulf of Mexico.

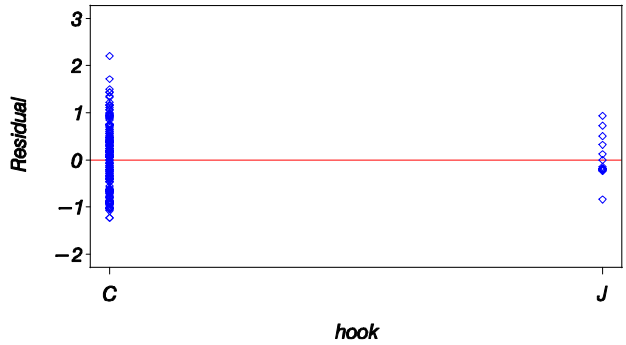
a. Chi-square residuals by year.



c. Chi-square residuals by depthzone.



b. Chi-square residuals by hook type.



d. QQplot of chi-square residuals.

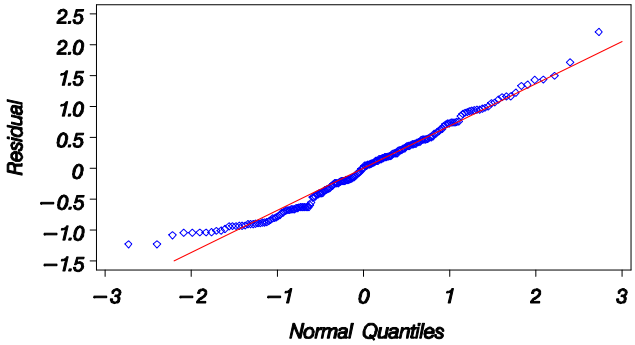
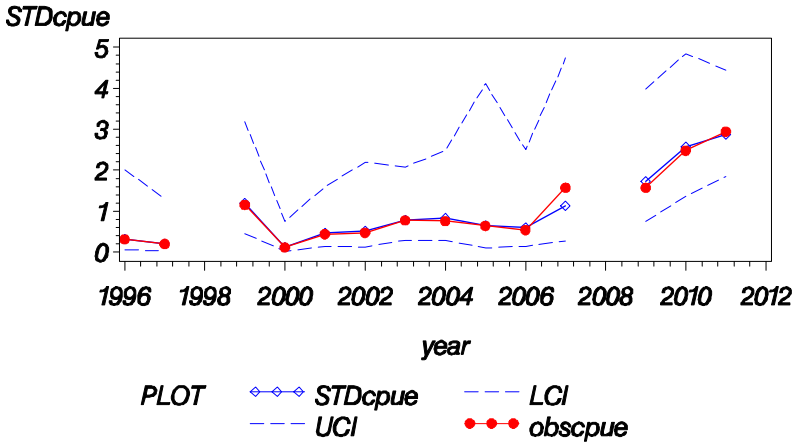


Table 4. Backward selection procedure for building delta-lognormal submodels for red snapper collected during Bottom Longline Surveys in the Eastern Gulf of Mexico. ** indicates the model chosen for the index.

Model Run #1	*Binomial Submodel Type 3 Tests (AIC = 9001.7)*						*Lognormal Submodel Type 3 Tests (AIC = 120.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	13	1419	25.62	1.97	0.0191	0.0199	12	58	1.02	0.4391
hook	1	1419	1.48	1.48	0.2240	0.2242	0	.	.	.
depthzone	1	1419	0.42	0.42	0.5167	0.5168	1	58	1.36	0.2490
Model Run #2	*Binomial Submodel Type 3 Tests (AIC = 10206.4)*						*Lognormal Submodel Type 3 Tests (AIC = 120.2)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	13	1589	23.87	1.84	0.0323	0.0332	13	58	1.04	0.4284
hook	1	1589	1.67	1.67	0.1967	0.1969	dropped			
depthzone	dropped						1	58	1.36	0.2490
Model Run #3*	*Binomial Submodel Type 3 Tests (AIC = 10004.7)*						*Lognormal Submodel Type 3 Tests (AIC = 119.6)*			
Effect	*Num DF*	*Den DF*	*Chi-Square*	*F Value*	*Pr > ChiSq*	*Pr > F*	*Num DF*	*Den DF*	*F Value*	*Pr > F*
year	13	1590	32.97	2.54	0.0017	0.0019	13	59	1.02	0.4493
hook	dropped						dropped			
depthzone	dropped						dropped			

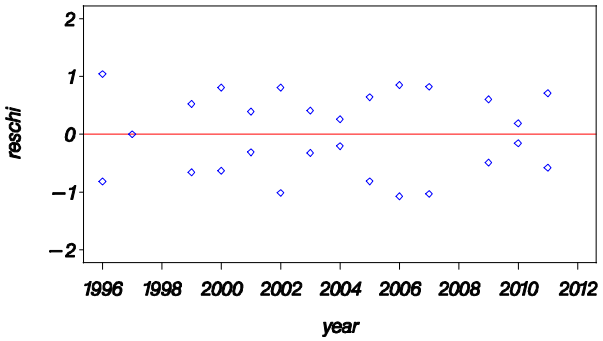
Figure 9. East Gulf abundance indices for red snapper collected during Bottom Longline Surveys. STDcpue is the index scaled to a mean of one over the time series. Obscpue is the average nominal CPUE, and LCI and UCI are 95% confidence limits. In the table below, the *frequency* listed is nominal frequency, *N* is the number of bottom longline stations, *Index* is the abundance index in CPUE units, *Scaled Index* is the index scaled to a mean of one over the time series, *CV* is the coefficient of variation on the index value, and *LCL* and *UCL* are 95% confidence limits.



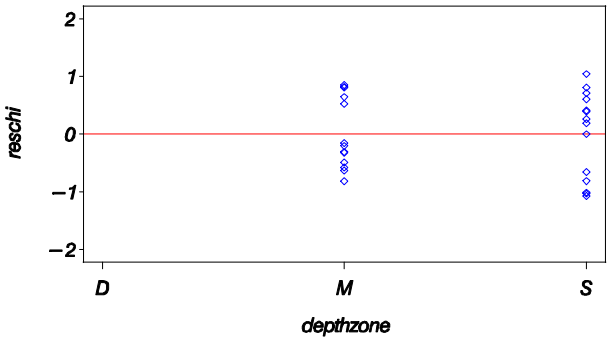
Survey Year	Frequency	N	Index	Scaled Index	CV	LCL	UCL
1996	0.01923	52	0.01989	0.31973	1.15337	0.05080	2.01230
1997	0.01389	72	0.01282	0.20605	1.15578	0.03265	1.30017
1999	0.03546	141	0.07450	1.19741	0.52048	0.44974	3.18801
2000	0.00775	129	0.00738	0.11866	1.15853	0.01875	0.75093
2001	0.02128	141	0.02927	0.47048	0.67350	0.13846	1.59867
2002	0.03175	63	0.03259	0.52371	0.81883	0.12500	2.19419
2003	0.02857	175	0.04855	0.78021	0.52186	0.29237	2.08204
2004	0.02740	145	0.05216	0.83827	0.58298	0.28416	2.47288
2005	0.02000	50	0.04068	0.65377	1.15303	0.10392	4.11311
2006	0.03448	58	0.03715	0.59708	0.81796	0.14268	2.49862
2007	0.02778	72	0.07019	1.12808	0.82008	0.26879	4.73448
2009	0.07368	95	0.10785	1.73327	0.43416	0.75495	3.97940
2010	0.12632	95	0.15987	2.56944	0.32563	1.36175	4.84820
2011	0.08571	315	0.17819	2.86383	0.22206	1.84665	4.44132

Figure 10. Diagnostic residual plots of the binomial submodel for red snapper collected during Bottom Longline Surveys in the Eastern Gulf of Mexico.

a. Chi-square residuals by year.



b. Chi-square residuals by depthzone.



c. QQplot of chi-square residuals.

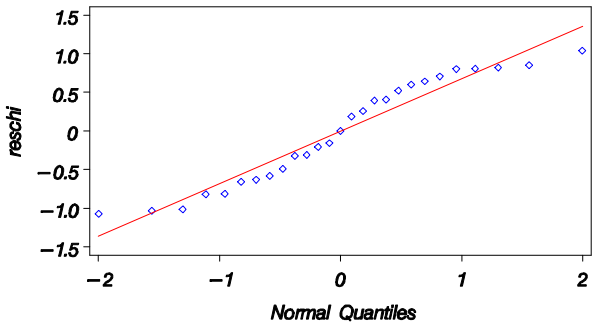
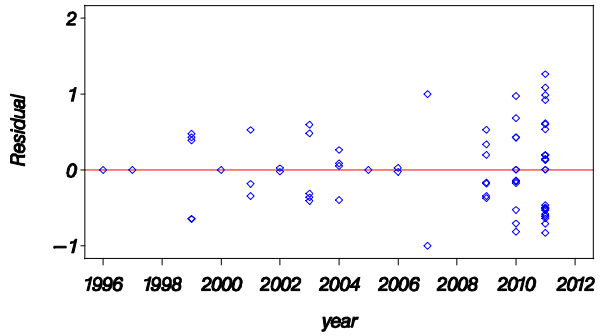


Figure 11. Diagnostic residual plots of the lognormal submodel for red snapper collected during Bottom Longline Surveys in the Eastern Gulf of Mexico.

a. Chi-square residuals by year.



b. Chi-square residuals by depthzone.

d. QQplot of chi-square residuals.

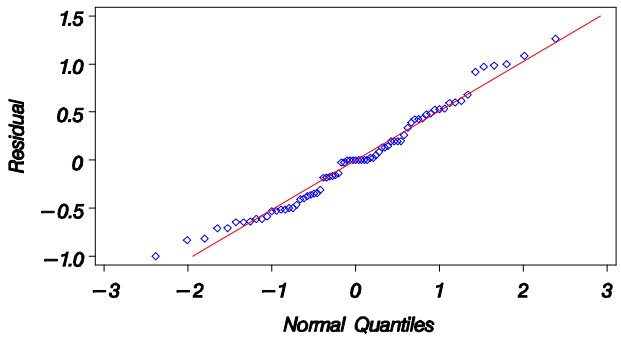


Figure 12. Age frequency of red snapper collected in Bottom Longline Surveys in the Gulf of Mexico.