Standardized indices of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys

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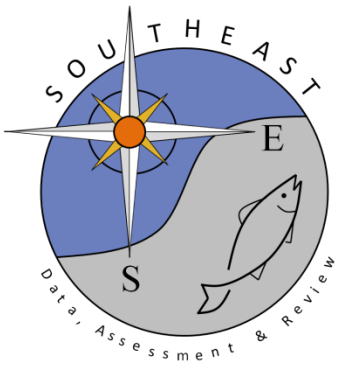
SEDAR77-DW29

Received: 1/7/2022



Please cite this document as:

McCandless, Camilla T. and Bryan S. Frazier. 2021. Standardized index of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys. SEDAR77-DW28. SEDAR, North Charleston, SC. 15 pp.

SEDAR 77 DATA WORKSHOP DOCUMENT

Standardized indices of abundance for scalloped hammerhead sharks from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys

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December 2021

Summary

This document details shark catches from the South Carolina Department of Natural Resources (SCDNR) adult red drum longline survey (1994-2006) and the SCDNR Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey (2007-2018), both conducted in South Carolina's estuarine and nearshore waters. Catch per unit effort (CPUE) in number of sharks per 100 hook hours were used to examine scalloped hammerhead shark relative abundance. The CPUE was standardized using generalized linear mixed models in a two-step delta-lognormal approach that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. The standardized CPUE results from the SCDNR red drum longline survey from 1996 to 2006 show no clear trend for the index values produced, but a notable peak in 2002. For the SCDNR SEAMAP longline survey the standardized CPUE results also show no clear trend across years for scalloped hammerhead relative abundance from 2008 to 2019 with a notable peak in 2013. This peak was also seen in blacktip shark relative abundance for the SCDNR SEAMAP longline survey during a previous assessment (SEDAR65-WP-07). Due to poor model diagnostics (SCDNR adult red drum survey) and the low proportion of positive catch sets (SCDNR SEAMAP survey), these scalloped hammerhead indices are not recommended for use during the SEDAR 77 assessment process.

Introduction

The South Carolina Department of Natural Resources (SCDNR) runs a long-term monitoring program for adult red drum, *Sciaenops ocellatus,* in the coastal waters of South Carolina. A fixed-station longline survey was conducted from 1994 to 2006. Under the Southeast Area Monitoring and Assessment Program (SEAMAP), this survey was modified from a fixed-station survey to a random-stratified multispecies survey in 2007 in response to the needs of stock assessment biologists and to increase coverage along the coast. Both surveys have high shark catch rates and have been used in multiple shark stock assessments conducted under the Southeast Data Assessment and Review (SEDAR) process. Due to the differences in gear and sampling design, these surveys are modeled as two separate time series (1994-2006 and 2007-2019).

Methods

Sampling design

SCDNR red drum estuarine sampling was conducted primarily from April through October with the majority of the effort occurring between May and September. Nearshore sampling occurred from immediately outside of the surf zone to 8 km offshore with depths ranging from 3–15 m. These sites were primarily live-bottom areas with low relief, consisting of rock or marl outcrops that were encrusted with sessile invertebrates such as sponges, gorgonians and bryozoans. Nearshore sampling occurred throughout the year with the exception of February; however, nearshore sampling was most intense from September through mid-December. The locations of the SCDNR red drum fixed estuarine and nearshore sampling areas are shown in Figure 1.

In 2007, a new SEAMAP multispecies survey began to increase geographical and seasonal coverage. Thirty sites are randomly selected from a predetermined list of sites (40-100 sites/strata) during each sampling period (2- month periods: March/April. May/June, July/August, September/October, November/December). Each of four strata (Winyah Bay, Charleston Harbor, St. Helena Sound and Port Royal Sound) is sampled once during each time period (Figure 2). Specific sampling locations within each stratum have been identified and chosen due to bottom type, depth, and in some cases from previous sampling or suggestions from local charter captains.

Sampling gear and data collection

SCDNR red drum survey longline gear consisted of a 272 kg test monofilament mainline that was 1829 m in length, was equipped with stop sleeves at 30.5 m intervals to prevent gangions from sliding together when a large fish was captured, and had 30.5 m buoy lines attached at each end. The SCDNR red drum survey gangions consisted of a 0.5 m, 91 kg test monofilament leader, size 120 stainless steel longline snap, 4/0 swivel and either a 14/0 or 15/0 circle hook. SCDNR red drum survey sets consisted of 120 hooks baited with fish and soak times were limited to 45 minutes unless conditions or events dictated otherwise.

The SCDNR SEAMAP longline gear consisted of a 272 kg test monofilament mainline that was 610 m in length, was also equipped with stop sleeves at 30.5 m intervals to prevent gangions from sliding together when a large fish was captured, and had 30.5 m buoy lines attached at each end. The SEAMAP longline gangions also consisted of a 0.5 m, 91 kg test monofilament leader, size 120 stainless steel longline snap, 4/0 swivel and either a 14/0 or 15/0 circle hook. SCDNR SEAMAP sets consisted of 40 hooks baited with fish and soak times for these sets were also limited to 45 minutes unless conditions or events dictated otherwise.

Station location, water temperature, salinity, and time of day were recorded for each set for both gear types. The sex, weight, fork length, total length, and umbilical scar condition of all sharks were recorded. Umbilical scar condition was recorded in six categories: "umbilical remains," "fresh open," "partially healed," "mostly healed," "well healed," and none. Sharks were then tagged with either a NMFS blue rototag or steel tipped dart tag (M-tag) and released.

Data Analysis

Catch per unit effort (CPUE) in number of sharks per 100 hook hours were used to examine scalloped hammerhead shark relative abundance for the SCDNR red drum and SEAMAP longline surveys. The CPUEs were standardized using a delta-lognormal generalized linear mixed model, which models the proportion of positive sets separately from the positive catch. After initial exploratory analyses, factors considered as potential influences on SCDNR red drum catch were year (1996-2006), month (May-October), and depth (<6 m, 6-8.9 m, ≥ 9 m). Years 1994 and 1995 were excluded because spatial and temporal sampling effort was not consistent with the rest of the survey years. Only stations in the Charleston Harbor area were used because this region was sampled consistently across years. Temperature and Salinity were not recorded consistently and including these as factors would have greatly reduced the dataset given the exclusion of other regions. The proportion of sets with positive catch values was modeled assuming a binomial distribution with a logit link function and the positive catch sets were modeled assuming a lognormal distribution. For the SCDNR SEAMAP survey, the following factors were considered as potential influences on the catch: year (2007-2018), month (August-November), inshore and coastal strata for each region (Winyah Bay, Charleston Harbor, Saint Helena Sound, Port Royal Sound), depth (<6 m, 6-8.9 m, , ≥ 9 m), temperature (<20 deg C, ≥ 25 deg C), and salinity (<25 ppt, 25-29.9 ppt, ≥ 30 ppt). The proportion of sets with positive catch values was modeled assuming a binomial distribution with a logit link function and the positive catch sets were modeled assuming a lognormal distribution.

Models were fit in a stepwise forward manner adding one potential factor at a time after initially running a null model with no factors included. Each potential factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor resulting in the greatest reduction in deviance was then incorporated into the model provided the effect was significant at $\alpha = 0.05$ based on a Chi-Square test, and the deviance per degree freedom was reduced by at least 1% from the less complex model. This process was continued until no additional factors met the criteria for incorporation into the final model. The factor "year" was kept in all final models, regardless of its significance, to allow for calculation of indices. All models in the stepwise approach were fitted using the SAS GENMOD procedure (SAS Institute, Inc.). The final models were then run through the SAS GLIMMIX macro to allow fitting of the generalized linear mixed models using the SAS MIXED procedure (Wolfinger, SAS Institute, Inc). The standardized indices of abundance were based on the year effect least square means determined from the combined binomial and lognormal components.

Results

A total of 46 scalloped hammerhead sharks were caught during the 793 SCDNR red drum longline sets from May through October, 1996 to 2006 and included in these analyses for index development. For the SCDNR SEAMAP longline survey, a total of 44 scalloped hammerhead sharks were caught during the 4095 longline sets from August through November, 2007 to 2019 included in these analyses for index development. The size range of scalloped hammerhead sharks caught by year is displayed in Figures 3 and 4 and for the SCDNR red drum and SEAMAP surveys, respectively. The proportion of SCDNR red drum survey sets with positive catch (at least one shark caught) was 5% and the proportion of SCDNR SEAMAP survey sets with positive catch was 1% for scalloped hammerhead sharks. The stepwise construction of each model is detailed in Tables 1 and 3 for total SCDNR red drum and SEAMAP

surveys, respectively. Model diagnostic plots for SCDNR red drum and SEAMAP surveys are found in Figure 5 (red drum) and Figures 7 (binomial SEAMAP) and 8 (lognormal SEAMAP). The resulting standardized indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Tables 2 and 4 and are plotted by year in Figures 6 and 9. The standardized CPUE results from the SCDNR red drum longline survey from 1996 to 2006 show no real trend for the index values produced, but a notable peak in 2002. For the SCDNR SEAMAP longline survey the standardized CPUE results also show no clear trend across years for scalloped hammerhead relative abundance from 2008 to 2019 with a notable peak in 2013; no scalloped hammerheads were caught in 2007. The peak in 2013 was also seen in blacktip shark relative abundance for the SCDNR SEAMAP longline survey during a previous assessment (SEDAR65-WP-07). Due to poor model diagnostics (SCDNR adult red drum survey, Figure 5) and the low proportion of positive catch sets (SCDNR SEAMAP survey, Table 4), these scalloped hammerhead indices are not recommended for use during the SEDAR 77 assessment process.

Table 1. Results of the stepwise procedure for development of the SCDNR red drum survey catch rate model for scalloped hammerhead sharks. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	99	110.2644	1.1138				
year	89	62.1753	0.6986	37.2778		48.09	<.0001
month	94	103.1320	1.0971	1.4994		7.13	0.2110
depth	97	108.3508	1.1170	-0.2873		1.91	0.3841

FINAL MODEL: year

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	34	8.1779	0.2405				
year	28	5.3280	0.1903	20.8732		15.00	0.0203
month	30	6.6655	0.2222	7.6091		7.16	0.1278
depth	32	8.0567	0.2518	-4.6985		0.52	0.7701

FINAL MODEL: year

Table 2. SCDNR red drum survey scalloped hammerhead shark analysis number of model observations per year (n obs), number of positive model observations per year (obs pos), proportion of positive model observations per year (obs ppos), nominal cpue as sharks per net hour (obs cpue), resulting estimated cpue from the model (est cpue), the lower 95% confidence limit for the est cpue (LCL), the upper 95% confidence limit for the est cpue (UCL), and the coefficient of variation for the estimated cpue (CV).

year	n obs	obs pos	obs ppos	obs cpue	est cpue	LCL	UCL	CV
1996	17	0	0.0000	0.0000				
1997	19	2	0.1053	0.2193	0.2320			
1998	17	0	0.0000	0.0000				
1999	12	1	0.0833	0.0926	0.0926	0.0349	0.2457	0.5185
2000	10	0	0.0000	0.0000				
2001	9	1	0.1111	0.1852	0.1852	0.0698	0.4914	0.5185
2002	10	4	0.4000	3.7167	3.5430	2.0766	6.0448	0.2719
2003	16	6	0.3750	1.8037	1.5405	0.9884	2.4010	0.2246
2004	14	0	0.0000	0.0000				
2005	18	7	0.3889	1.0759	1.1897	0.7867	1.7990	0.2090
2006	30	3	0.1000	0.1456	0.1583	0.0861	0.2910	0.3116

Table 3. Results of the stepwise procedure for development of the SCDNR SEAMAP catch rate model for scalloped hammerhead sharks. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	607	232.0287	0.3823				
year	595	208.2170	0.3499	8.4750		29.17	0.0037
stratum	600	222.8230	0.3714	2.8512		14.57	0.0419
sal	604	228.5786	0.3784	1.0201		3.45	0.3273
depth	606	231.7784	0.3825	-0.0523		0.25	0.6169
month	604	236.4803	0.3915	-2.4065		0.91	0.8226
temp	606	237.3297	0.3916	-2.4326		0.06	0.8030
year + stratum	588	193.0094	0.3282	14.1512	5.6762	15.21	0.0334
year + stratum + year*stratum	504	131.5248	0.2610	31.7290	17.5778	Negative of hessian	

FINAL MODEL: year + stratum

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	39	2.1896	0.0561				
sal	37	1.2932	0.0350	37.6114		21.87	<.0001
year	29	1.0423	0.0359	36.0071		30.71	0.0012
stratum	33	1.7864	0.0541	3.5651		8.62	0.2808
temp	39	2.1837	0.0560	0.1783		0.39	0.5313
depth	38	2.1896	0.0576	-2.6738		0.00	0.9923
month	37	2.174	0.0588	-4.8128		0.53	0.9127
sal + year	26	0.6775	0.0261	53.4759	15.8645	26.51	0.0055
sal + year + year*sal	21	0.5171	0.0246	56.1497	2.6738	11.08	0.0499

	AIC	BIC	(-2) Res Log likelihood
MIXED MODELS:			
sal + year	-4.9	-3.9	-6.9
sal + year+ year*sal	Not Negative of hessian, but did not converge		

FINAL MODEL: sal + year

Table 4. SCDNR SEAMAP scalloped hammerhead shark analysis number of model observations per year (n obs), number of positive model observations per year (obs pos), proportion of positive model observations per year (obs ppos), nominal cpue as sharks per net hour (obs cpue), resulting estimated cpue from the model (est cpue), the lower 95% confidence limit for the est cpue (LCL), the upper 95% confidence limit for the est cpue (UCL), and the coefficient of variation for the estimated cpue (CV).

year	n obs	obs pos	obs ppos	obs cpue	est cpue	LCL	UCL	CV
2007	128	0	0.0000	0.0000				
2008	158	2	0.0127	0.0696	0.0740	0.0132	0.4156	1.0515
2009	183	4	0.0219	0.0930	0.1075	0.0286	0.4045	0.7424
2010	286	7	0.0245	0.1142	0.1450	0.0512	0.4107	0.5579
2011	242	1	0.0041	0.0117	0.0143	0.0016	0.1242	1.4883
2012	265	1	0.0038	0.0172	0.0204	0.0024	0.1776	1.4890
2013	266	12	0.0451	0.1957	0.2484	0.1108	0.5570	0.4207
2014	293	2	0.0068	0.0250	0.0325	0.0058	0.1827	1.0513
2015	270	2	0.0074	0.0285	0.0404	0.0072	0.2277	1.0540
2016	307	2	0.0065	0.0500	0.0413	0.0073	0.2339	1.0582
2017	309	3	0.0097	0.0346	0.0420	0.0095	0.1854	0.8570
2018	300	5	0.0166	0.0687	0.0833	0.0249	0.2785	0.6625
2019	302	1	0.0033	0.0160	0.0207	0.0024	0.1806	1.4920

Figure 1. SCDNR red drum survey fixed estuarine and nearshore sampling stations

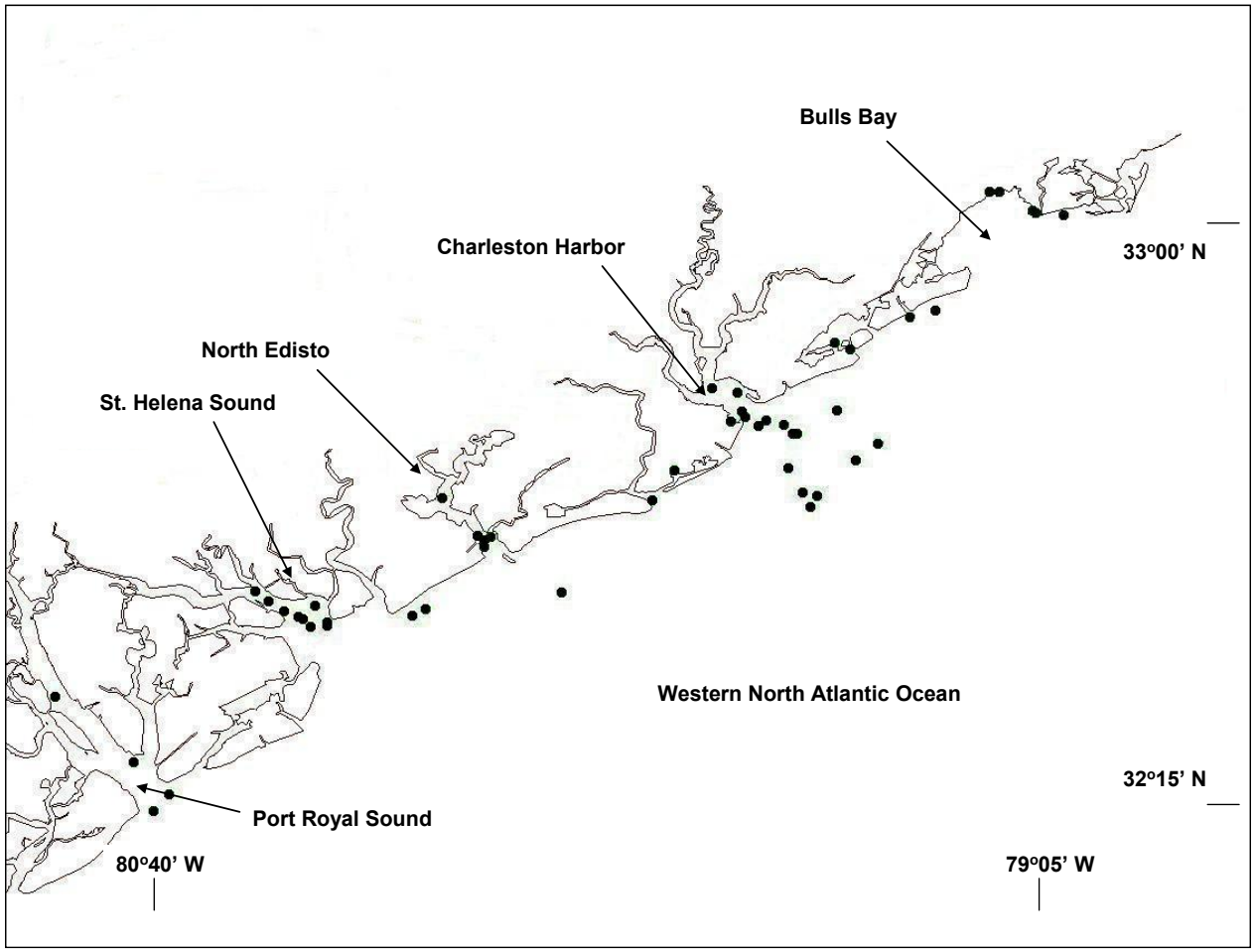


Figure 2. SCDNR SEAMAP longline survey sampling areas

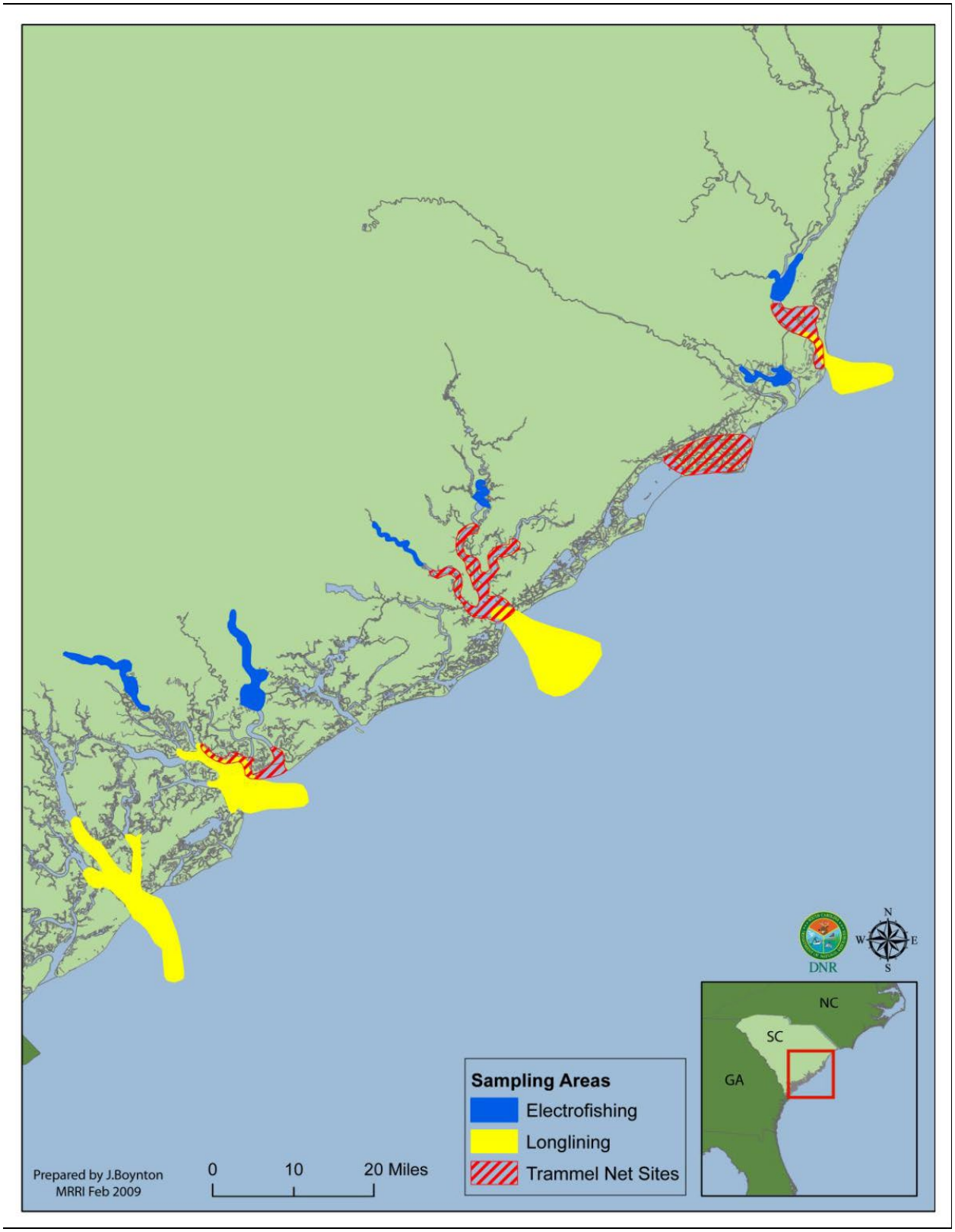


Figure 3. Fork lengths (cm) of scalloped hammerhead sharks caught during the SCDNR red drum longline survey from May through October, 1996-2006.

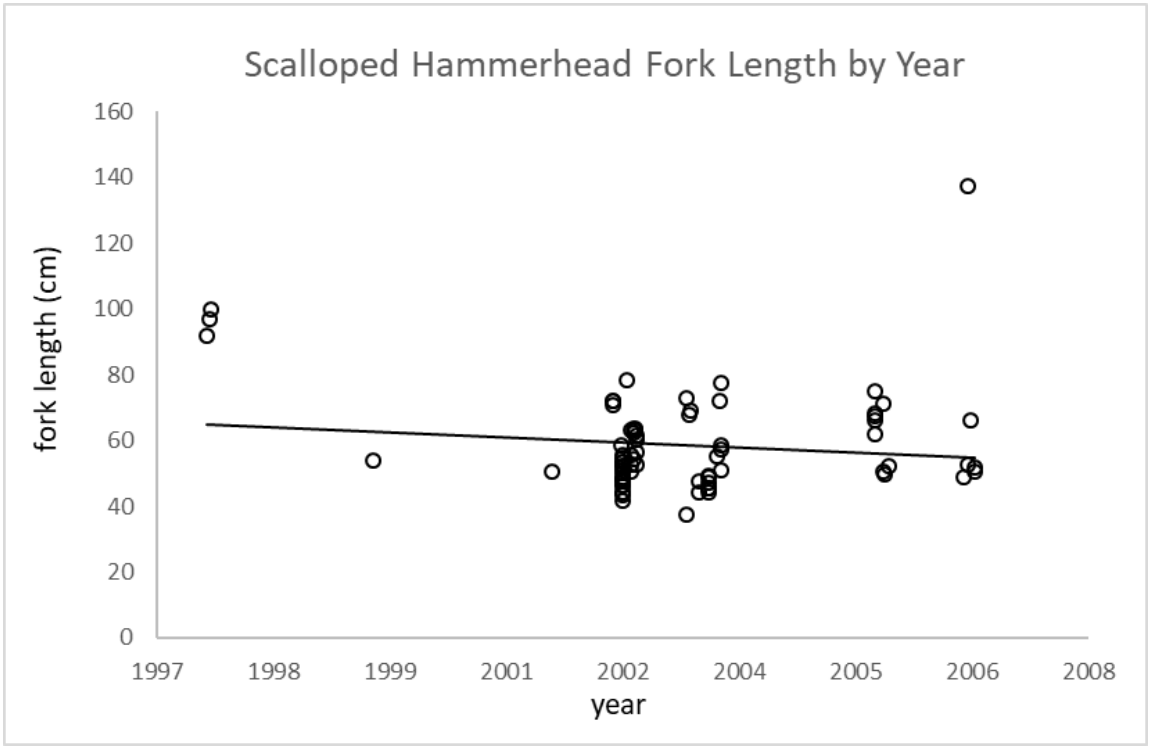


Figure 4. Fork lengths (cm) of scalloped hammerhead sharks caught during the SCDNR SEAMAP longline survey from August through November, 2007-2019.

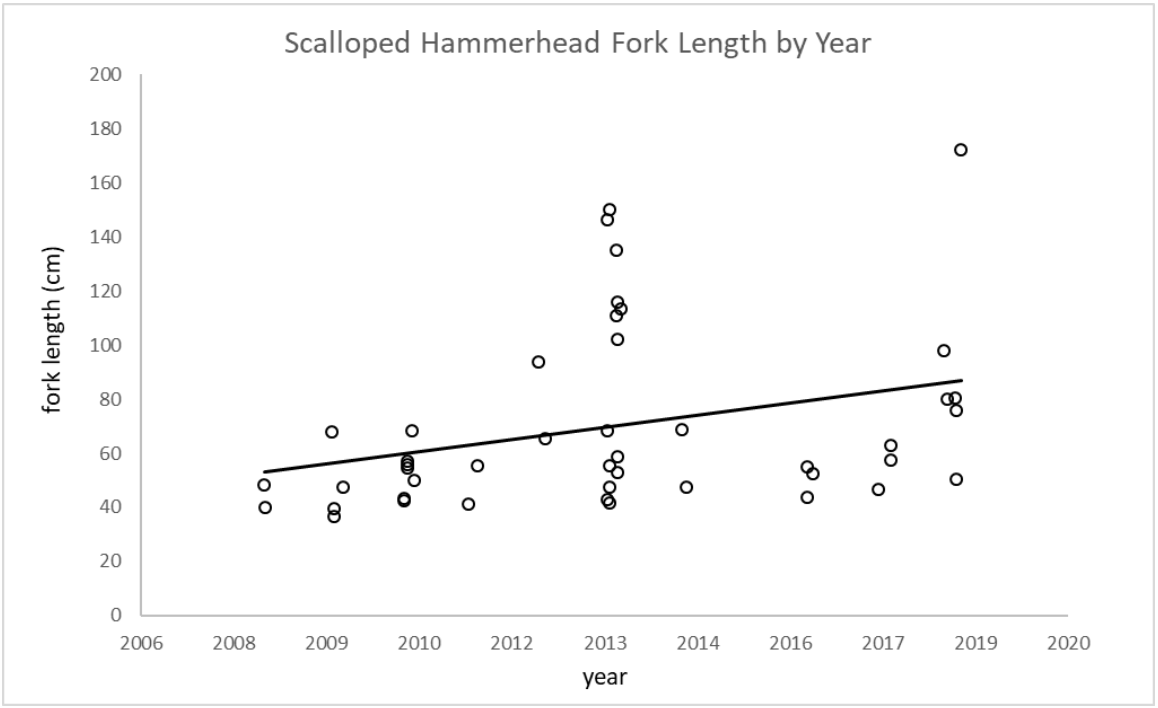
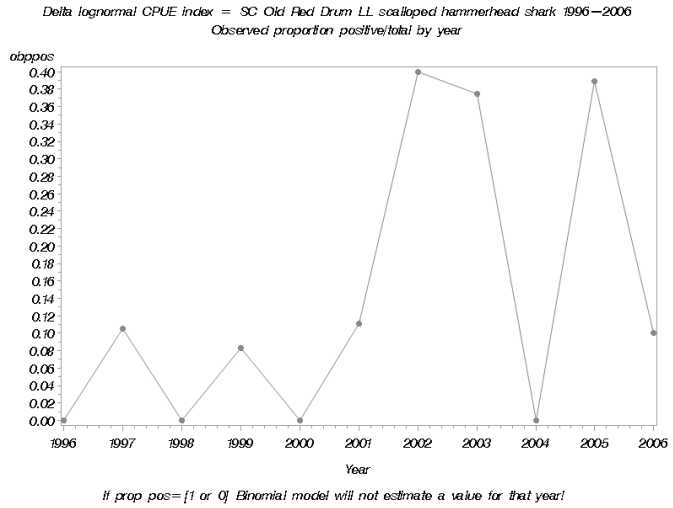
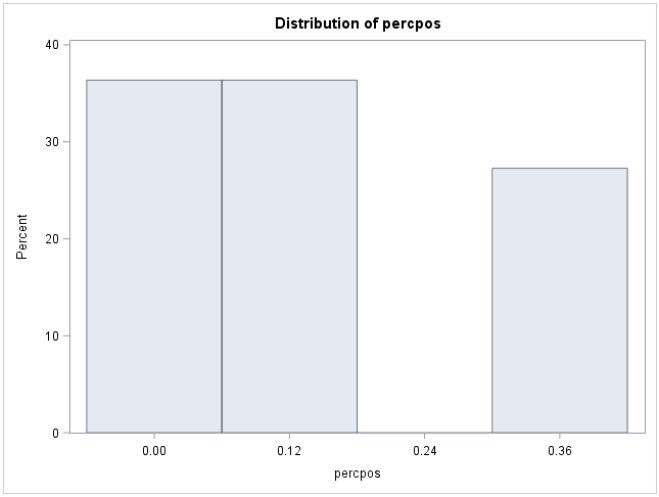
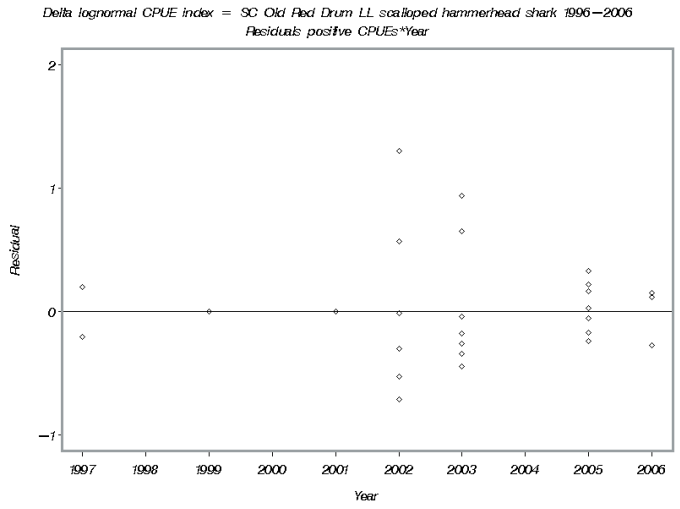
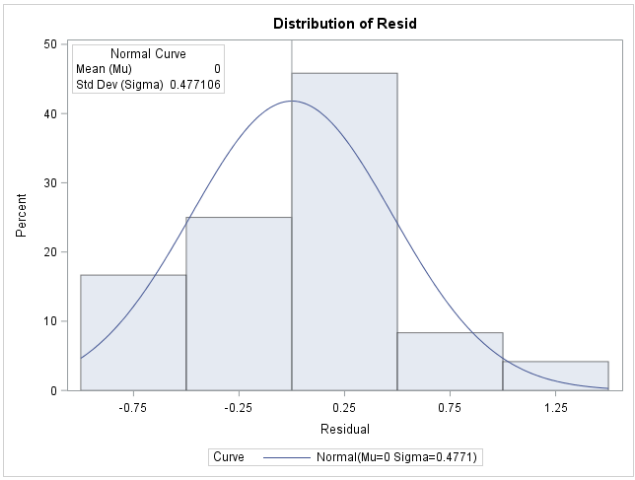


Figure 5. Diagnostic plots for the scalloped hammerhead model from the SCDNR red drum survey.









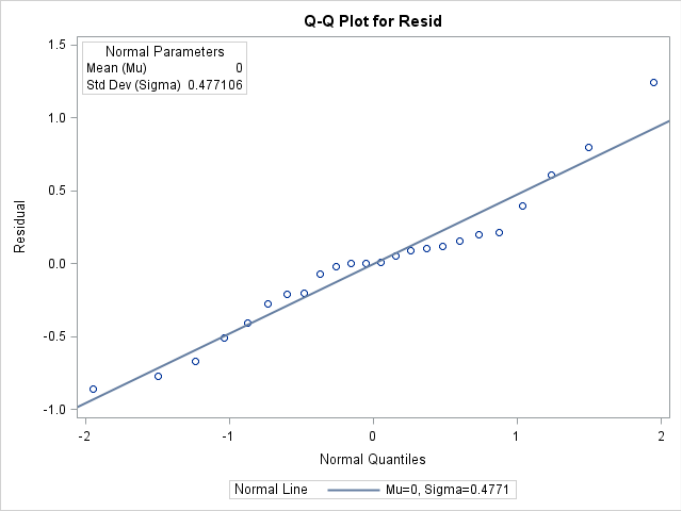


Figure 6. SCDNR red drum survey scalloped hammerhead shark nominal (obscpue1) and estimated (stdcpue1) indices with 95% confidence limits (LCI1, UCI1).

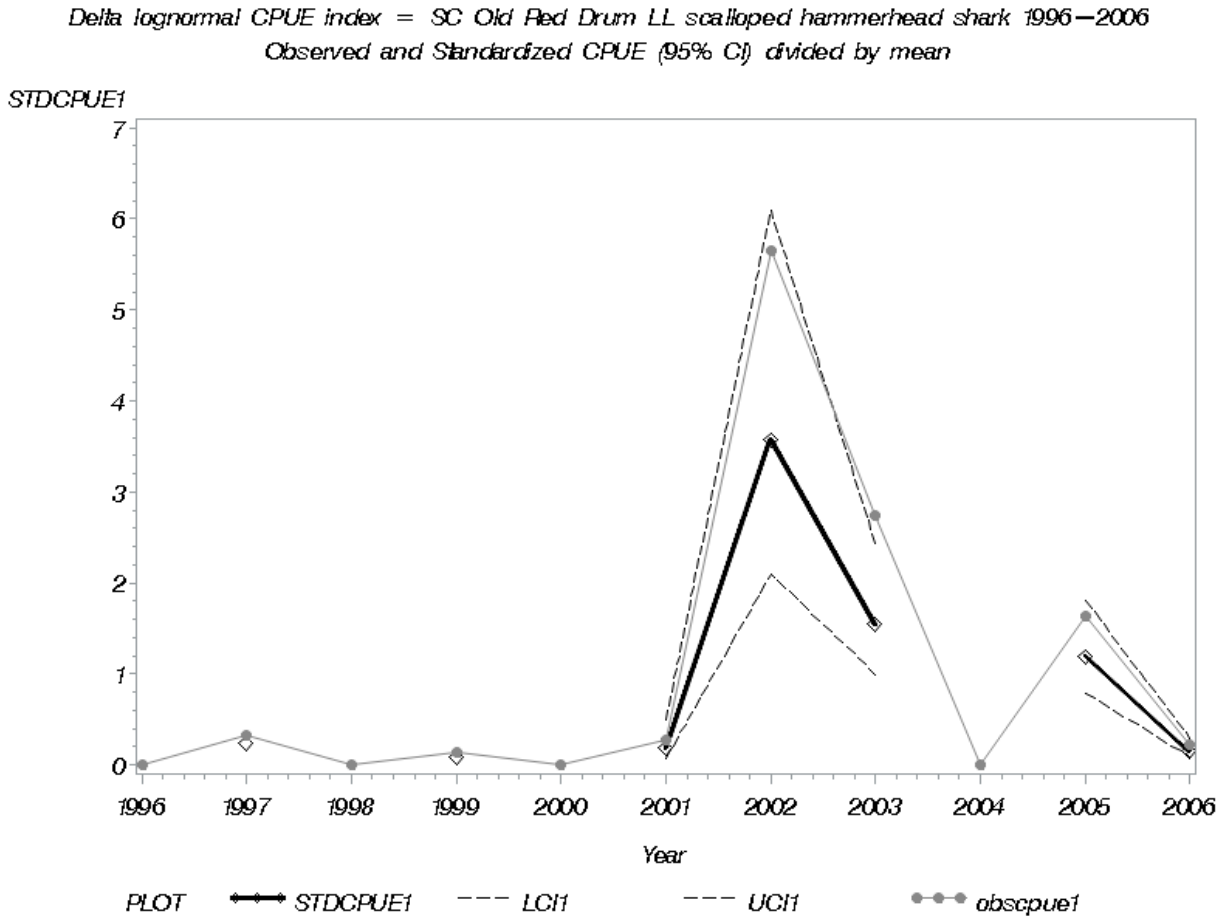
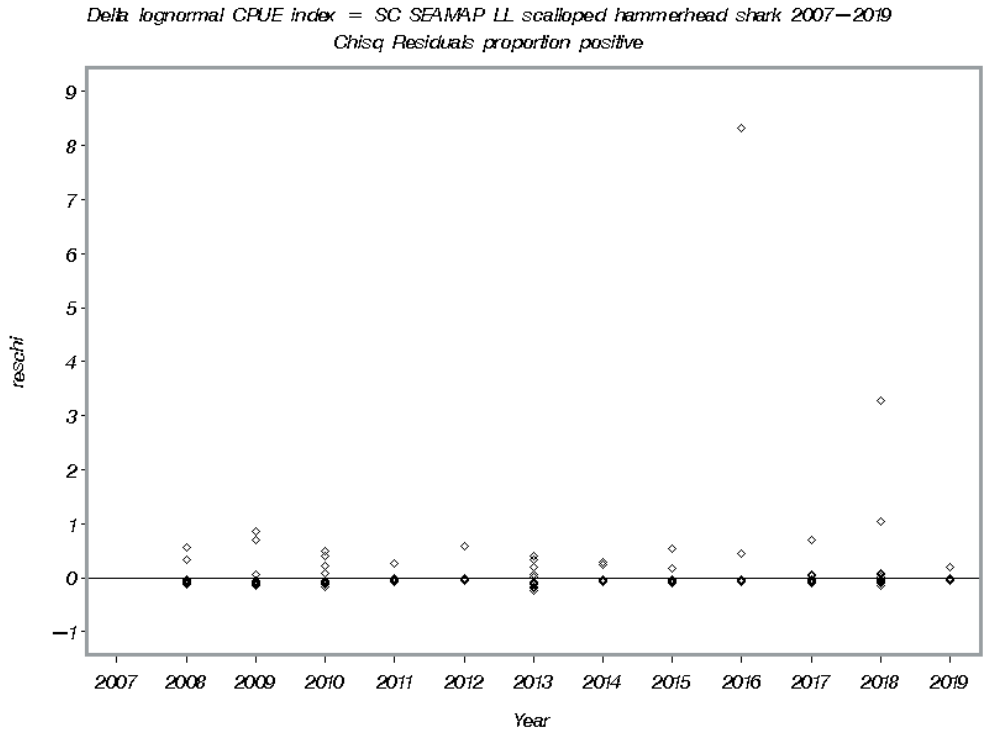


Figure 7. SCDNR SEAMAP longline survey scalloped hammerhead shark model diagnostic plots for the binomial component.



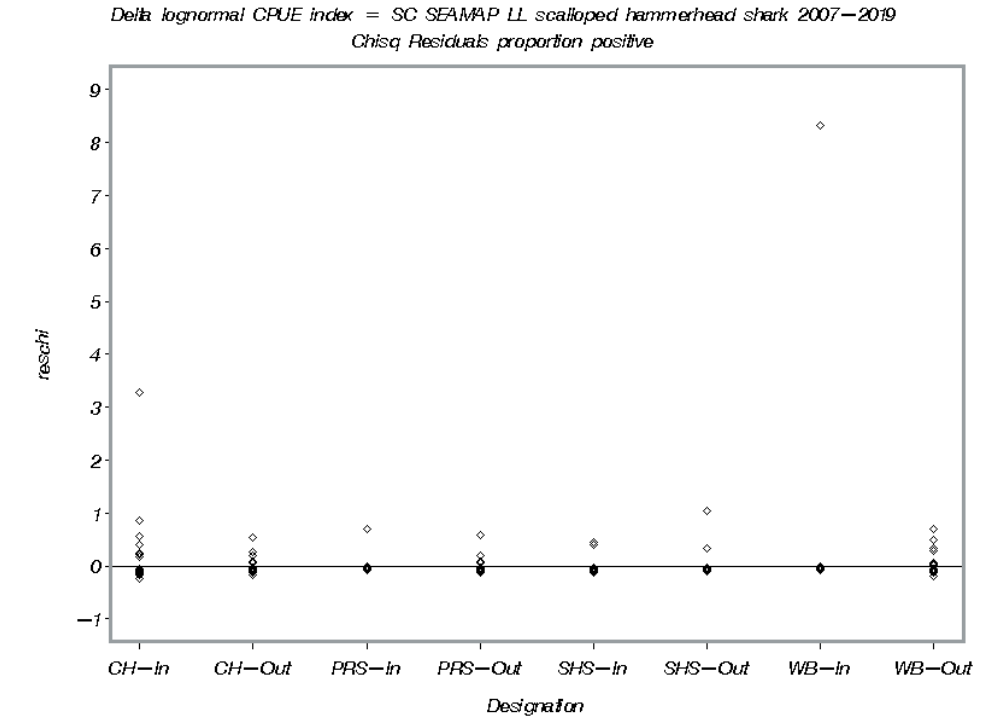
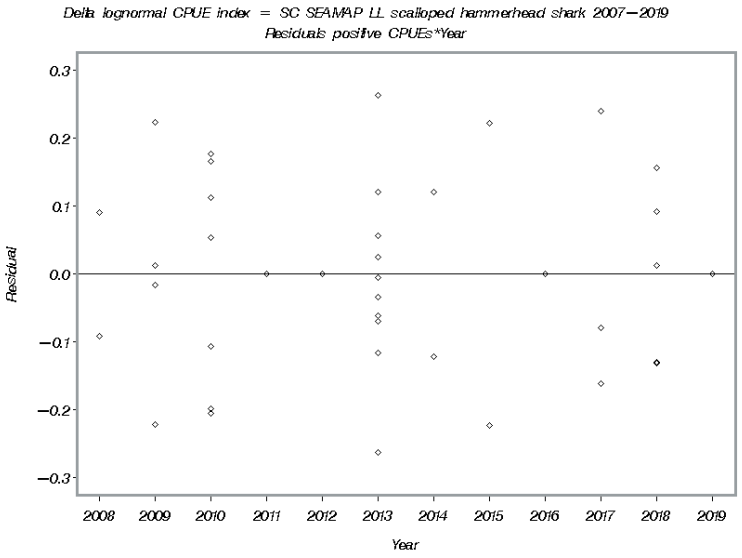
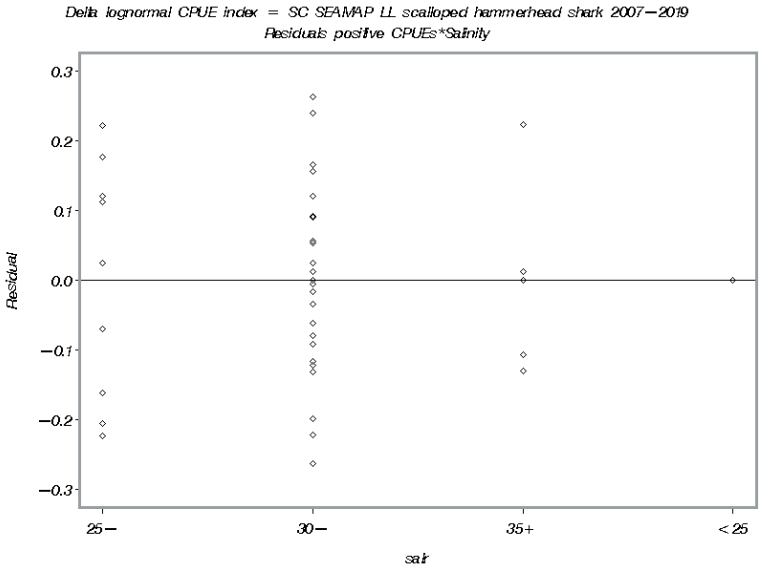
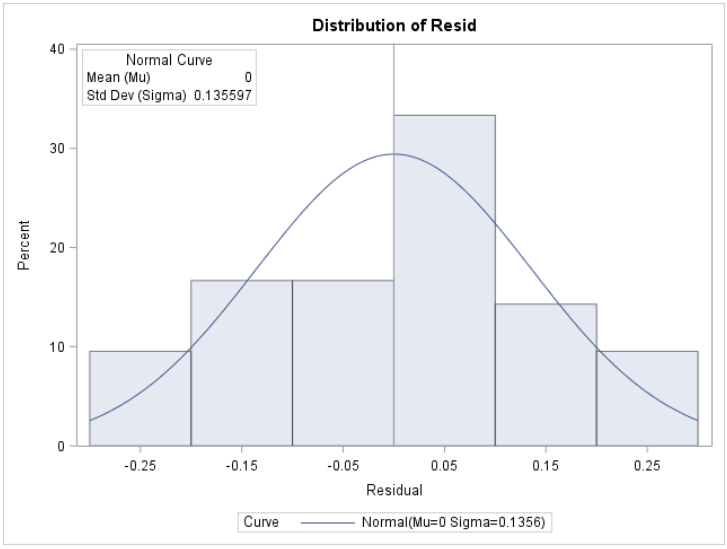


Figure 8. SCDNR SEAMAP longline survey scalloped hammerhead shark model diagnostic plots for the lognormal component.







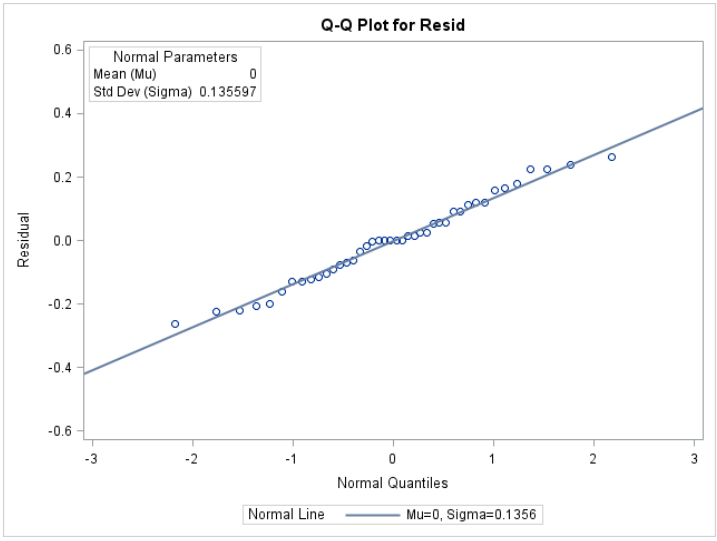


Figure 9. SCDNR SEAMAP longline survey scalloped hammerhead shark nominal (obscpue1) and standardized (stdcpue1) indices with 95% confidence limits (LCI1, UCI1).