Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys

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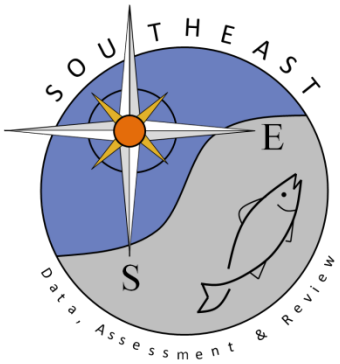

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SEDAR 65 DATA WORKSHOP DOCUMENT

Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the South Carolina Department of Natural Resources red drum and Southeast Area Monitoring and Assessment Program longline surveys

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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 blacktip shark relative abundance. The CPUE was standardized using generalized linear 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 indicate a variable but slight decreasing trend overall in blacktip shark relative abundance across survey years from 1996 to 2006. The standardized CPUE results from the SCDNR SEAMAP longline survey indicate a variable but slight increasing trend overall in blacktip shark relative abundance across survey years from 2007 to 2018 with a notable peak in 2013. This peak was also seen in the SCDNR long-gillnet Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) survey (SEDAR65-DW07) and, not as pronounced, in the COASTSPAN longline survey (SEDAR65-DW08).

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 (1996-2006 and 2007-2018).

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 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 blacktip shark relative abundance for the SCDNR red drum and SEAMAP longline surveys. The CPUEs were standardized using a delta-lognormal generalized linear 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-September), 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 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 190 blacktip sharks were caught during the 902 SCDNR red drum longline sets from 1996 to 2006 included in these analyses for index development. For the SCDNR SEAMAP longline survey, a total of 622 blacktip sharks were caught during the 3744 longline sets from 2007 to 2018 included in these analyses for index development. The size range of blacktip sharks caught by year is displayed in Figures 3 and 4. The proportion of SCDNR red drum survey sets with positive catch (at least one blacktip shark caught) was 13% and the proportion of SCDNR SEAMAP survey sets with positive catch (at least one blacktip shark caught) was 11%. The stepwise construction of each model and the resulting statistics are detailed in Tables 1 and 3 for total SCDNR red drum survey and SEMAP survey blacktip

sharks, respectively. Model diagnostic plots reveal that the model fit is acceptable for both SCDNR red drum survey blacktip sharks (Figures 5 and 6) and for SEAMAP blacktip sharks (Figures 8 and 9). The resulting 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 7 and 10. Nominal and standardized CPUE results from the SCDNR red drum longline survey indicate a variable but slight decreasing trend overall in blacktip shark relative abundance across survey years from 1996 to 2006. The standardized CPUE results from the SCDNR SEAMAP longline survey indicate a variable but slight increasing trend overall in blacktip shark relative abundance across survey years from 2007 to 2018 with a notable peak in 2013. This peak was also seen in the SCDNR Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) long-gillnet survey (SEDAR65-DW07) and, not as pronounced, in the COASTSPAN longline survey (SEDAR65-DW08).

Table 1. Results of the stepwise procedure for development of the SCDNR red drum survey catch rate model for blacktip 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. L is the log likelihood.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	99	133.4342	1.3478				
depth	97	127.2856	1.3122	2.6413		6.15	0.0462
year	89	117.6724	1.3222	1.8994		15.76	0.1067
month	94	126.8204	1.3492	-0.1039		6.61	0.2510
depth + year	87	113.7378	1.3073	3.0049	0.3636	13.55	0.1946

FINAL MODEL: depth + year

AIC 84.6 **BIC** 85.4 **(-2) Res LL** 82.6

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	depth	year
DF	2	10
CHI SQUARE	1.28	4.48

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	81	47.7164	0.5891				
year	71	40.1440	0.5654	4.0231		14.17	0.1654
month	76	44.2962	0.5828	1.0694		6.1	0.2967
depth	79	47.6116	0.6027	-2.3086		0.18	0.9138

FINAL MODEL: year

AIC 183.6 **BIC** 185.8 **(-2) Res LL** 181.6

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	year
DF	10
CHI SQUARE	13.39

Table 2. SCDNR red drum survey blacktip 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 (LCI), the upper 95% confidence limit for the est cpue (UCI), 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	22	7	0.3182	1.3333	1.2274	0.3802	3.9619	0.6400
1997	27	8	0.2963	2.1377	1.2726	0.4172	3.8821	0.6040
1998	28	8	0.2857	0.4436	0.4577	0.1485	1.4101	0.6102
1999	18	4	0.2222	0.4214	0.3944	0.0884	1.7588	0.8652
2000	34	13	0.3824	1.1887	1.3585	0.5847	3.1564	0.4409
2001	22	2	0.0909	0.3030	0.3487	0.0491	2.4747	1.2696
2002	32	6	0.1875	0.4747	0.5890	0.1618	2.1441	0.7197
2003	46	10	0.2174	0.9532	1.0194	0.3625	2.8672	0.5536
2004	36	5	0.1389	0.3560	0.4589	0.1137	1.8527	0.7920
2005	37	4	0.1081	0.2703	0.3098	0.0660	1.4540	0.9044
2006	52	15	0.2885	1.3632	1.3158	0.5749	3.0116	0.4324

Table 3. Results of the stepwise procedure for development of the SCDNR SEAMAP catch rate model for blacktip 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. L is the log likelihood.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	763	1232.0089	2.3866				
month	760	818.4851	1.0770	54.8730		413.52	<.0001
temp	761	844.7460	1.1100	53.4903		387.26	<.0001
stratum	756	1103.2276	1.4593	38.8544		128.78	<.0001
year	752	1204.5192	1.6018	32.8836		27.49	0.0039
depth	762	1226.8366	1.6100	32.5400		5.17	0.0229
sal	760	1226.9500	1.6144	32.3557		5.06	0.1675
month +							
stratum	753	669.7455	0.8894	62.7336	7.8606	148.74	<.0001
year	749	773.5856	1.0328	56.7250	1.8520	44.90	<.0001
temp	758	788.1495	1.0398	56.4317	1.5587	30.34	<.0001
depth	759	810.9300	1.0684	55.2334	0.3603	7.56	0.0060
month + stratum							
temp	751	627.6256	0.8357	64.9837	2.2501	42.12	<.0001
year	742	637.4880	0.8591	64.0032	1.2696	32.26	0.0007
month + stratum + temp +							
year	740	598.2180	0.8084	66.1275	1.1439	29.41	0.0020

FINAL MODEL: month + stratum + temp + year

AIC 2059.5 **BIC** 2153.8 **(-2) Res LL** 2176.9

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	month	stratum	temp	year
DF	3	7	1	11
CHI SQUARE	19.83	63.67	7.03	16.74

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	360	112.1932	0.3116				
month	357	103.6229	0.2903	6.8357		28.69	<.0001
year	349	102.2331	0.2929	6.0013		33.56	0.0004
stratum	353	104.3692	0.2957	5.1027		26.10	0.0005
temp	359	107.1140	0.2984	4.2362		16.72	<.0001
sal	357	111.5230	0.3124	-0.2567		2.16	0.5393
depth	359	112.0072	0.3120	-0.1284		0.60	0.4389
month +							
year	346	95.2690	0.2753	11.6496	5.6483	30.34	0.0014
stratum	350	97.2279	0.2778	10.8472	4.8460	23.00	0.0017
temp	356	103.5753	0.2909	6.6431	0.6418	0.17	0.6836
month + year +							
stratum	339	90.8095	0.2679	14.0244	2.3748	17.31	0.0155

FINAL MODEL: month + year + stratum

AIC 596.4 **BIC** 600.2 **(-2) Res LL** 594.4

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	month	year	stratum
DF	3	11	7
CHI SQUARE	21.17	25.31	17.87

Table 4. SCDNR SEAMAP blacktip 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 (LCI), the upper 95% confidence limit for the est cpue (UCI), 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	15	0.1163	0.7124	1.7214	0.8676	3.4155	0.3529
2008	158	8	0.0506	0.2754	0.8375	0.3200	2.1919	0.5103
2009	183	15	0.0820	0.3682	1.2200	0.6102	2.4395	0.3571
2010	291	28	0.0962	0.7374	0.8986	0.5101	1.5827	0.2888
2011	242	26	0.1074	1.0351	1.5343	0.8763	2.6863	0.2856
2012	265	32	0.1208	0.9184	1.5427	0.9320	2.5536	0.2560
2013	266	40	0.1504	1.3002	2.7065	1.7822	4.1101	0.2112
2014	292	44	0.1507	0.7443	1.7660	1.1870	2.6275	0.2006
2015	270	46	0.1704	1.1613	1.9826	1.3167	2.9854	0.2068
2016	307	30	0.0977	0.6178	0.9741	0.5747	1.6511	0.2685
2017	309	37	0.1197	0.6401	1.1241	0.7082	1.7843	0.2341
2018	300	46	0.1528	0.9866	1.4639	0.9489	2.2585	0.2194

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

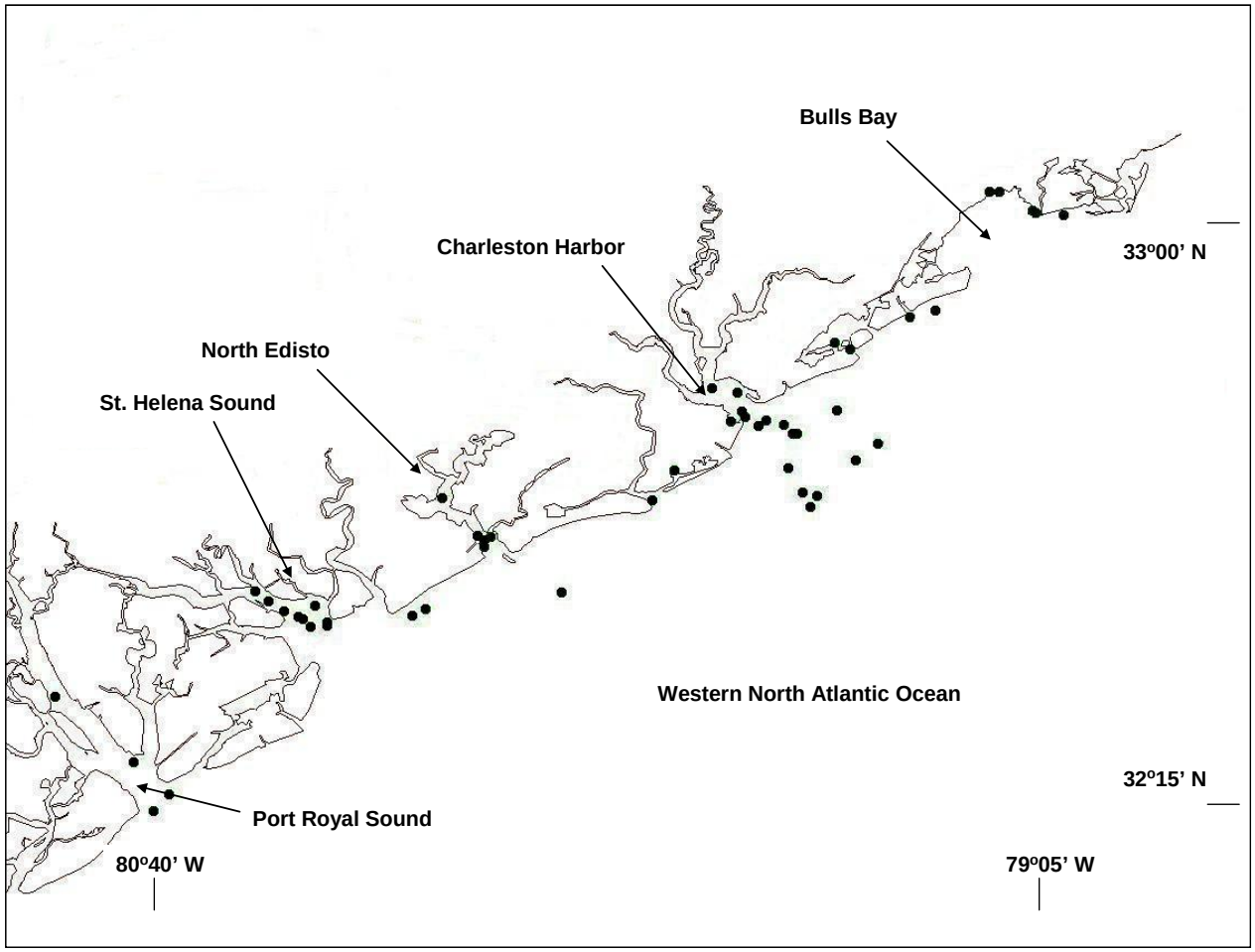


Figure 2. SCDNR SEAMAP longline survey sampling areas

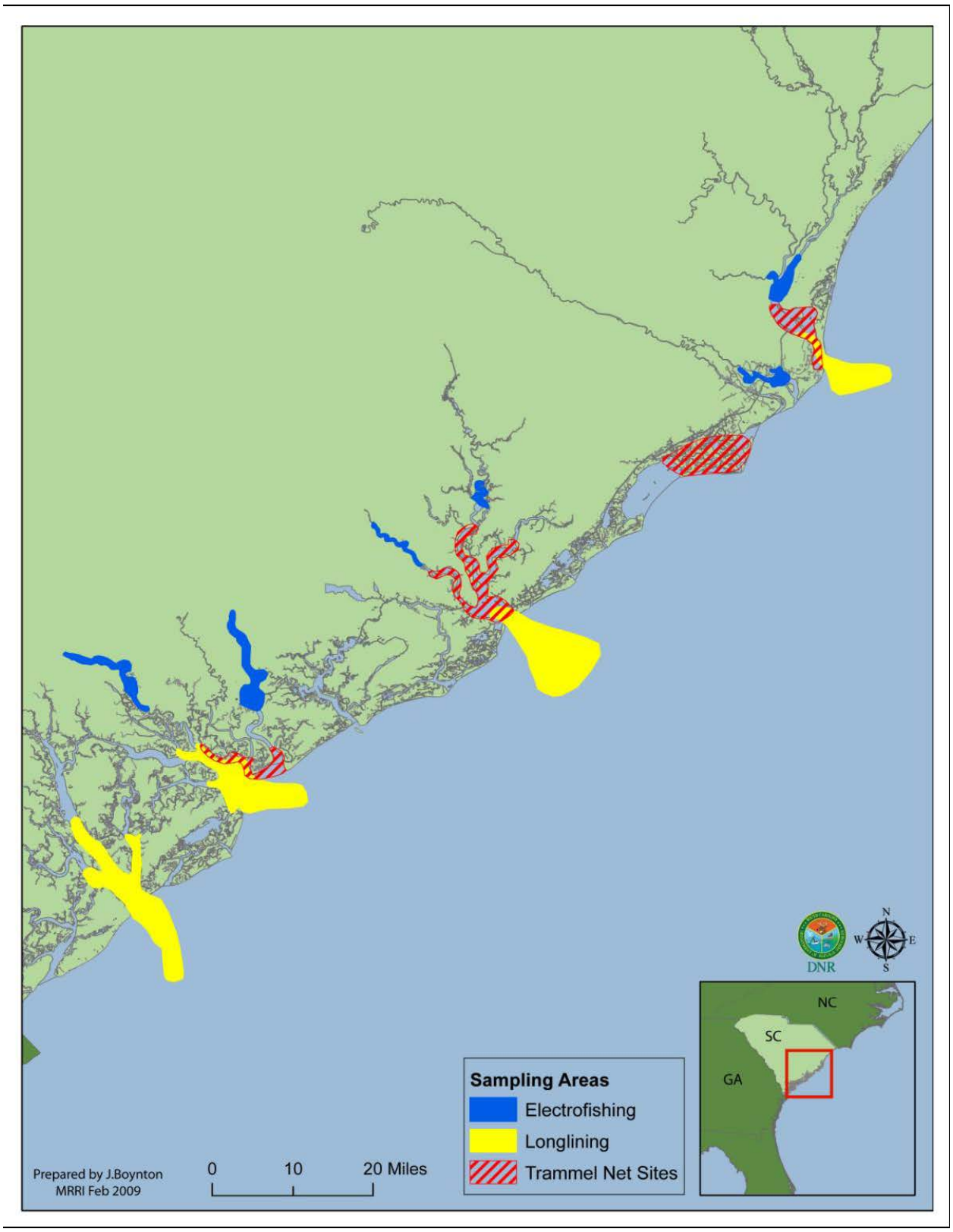


Figure 3. Fork lengths (cm) of blacktip sharks caught during the SCDNR red drum longline survey from 1994-2006.

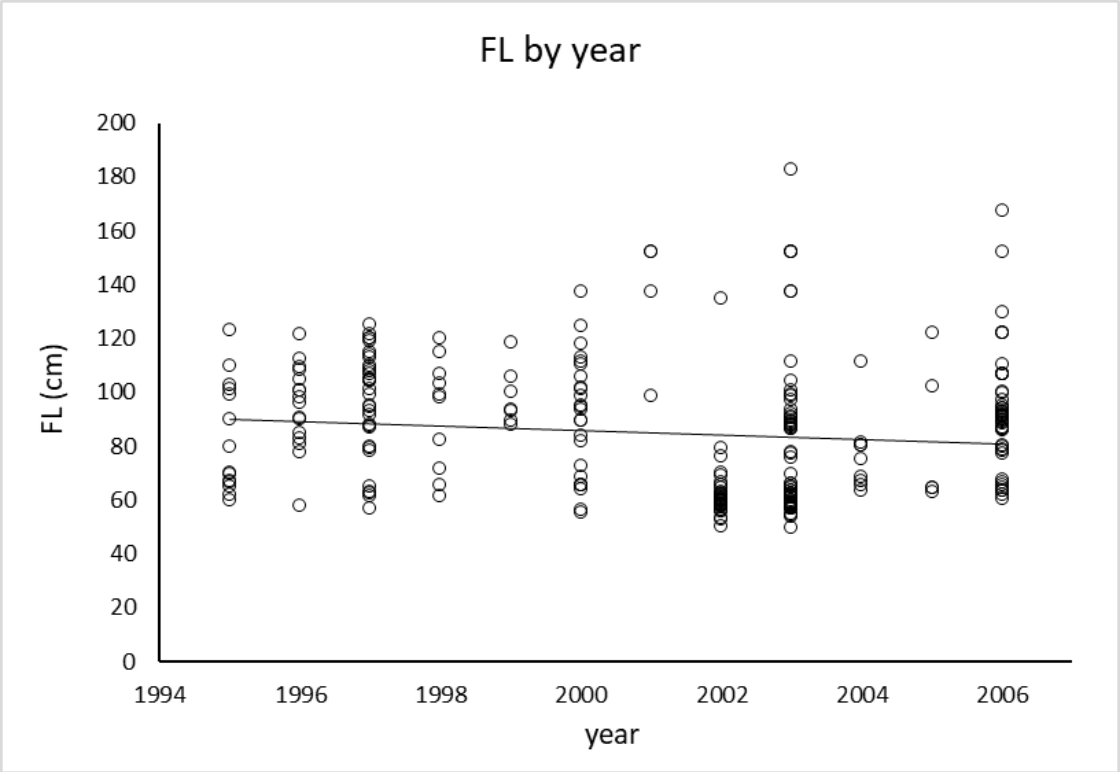


Figure 4. Fork lengths (cm) of blacktip sharks caught during the SCDNR SEAMAP longline survey from 2007-2018.

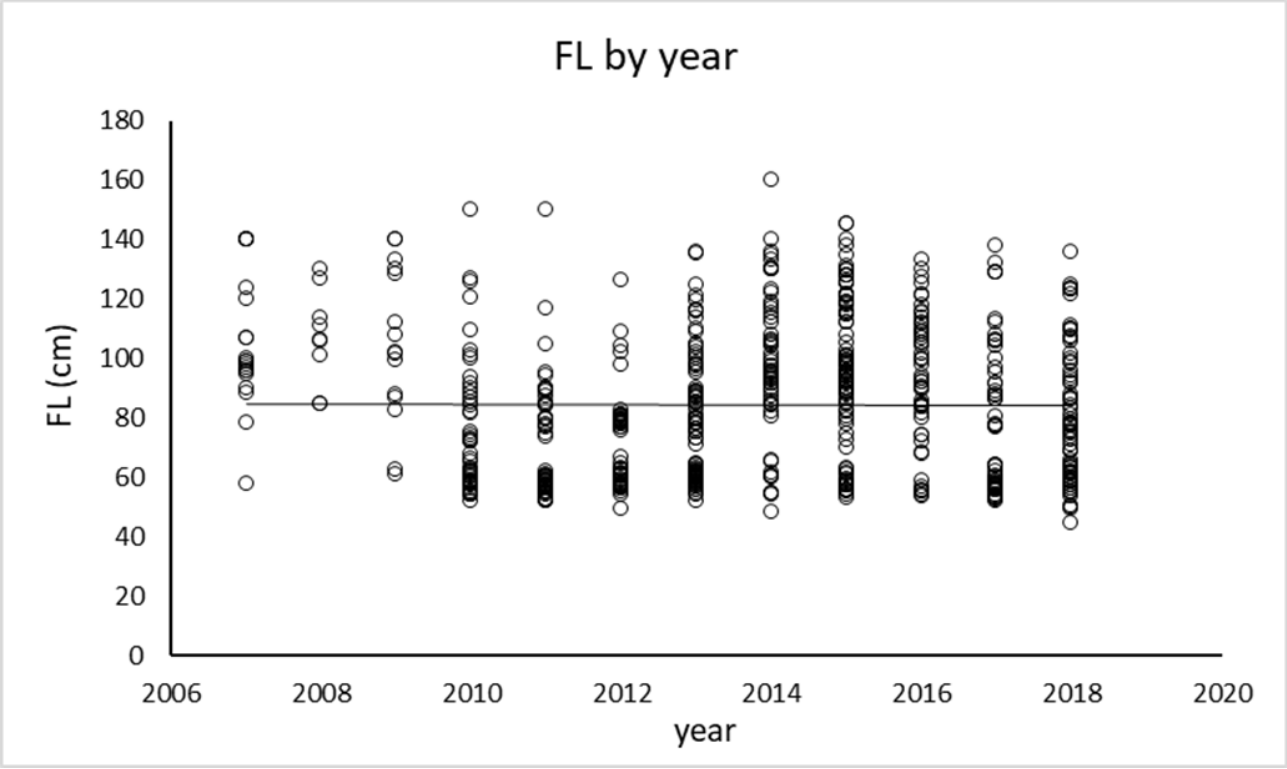
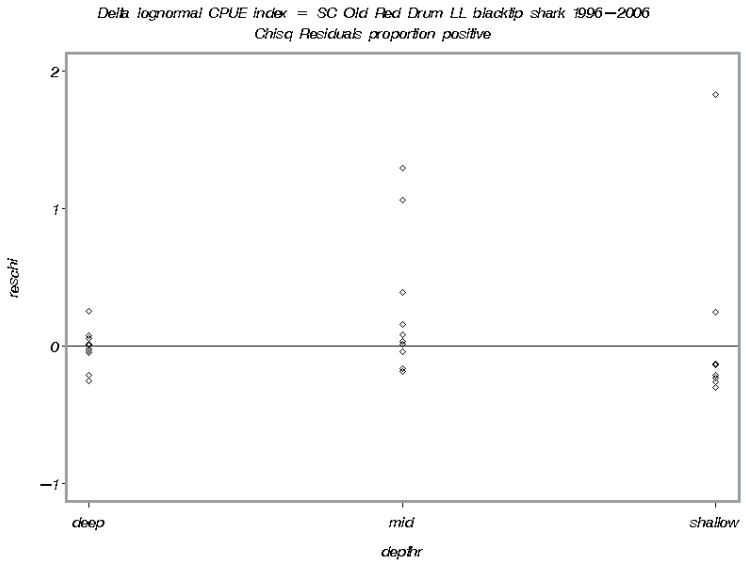


Figure 5. SCDNR red drum survey blacktip shark model diagnostic plots for the binomial component.



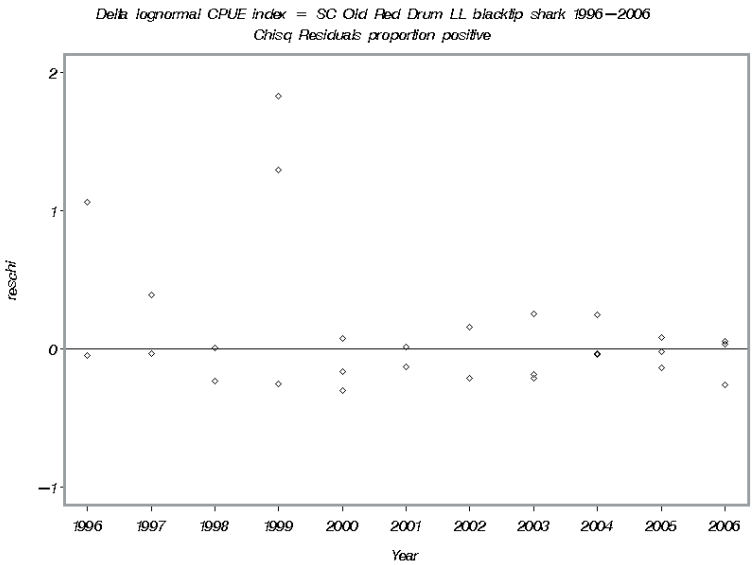
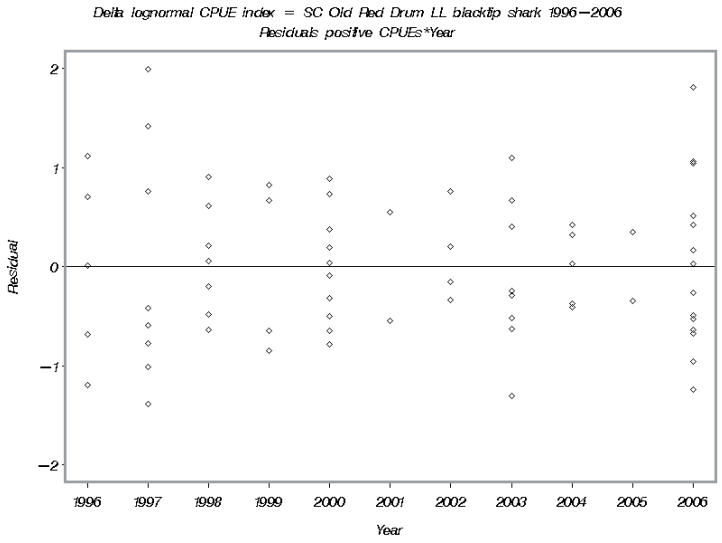
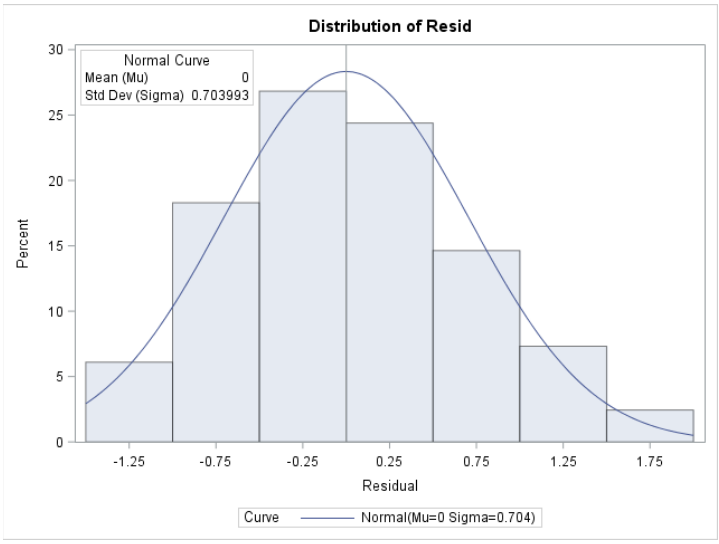


Figure 6. SCDNR red drum survey blacktip shark model diagnostic plots for the lognormal component.





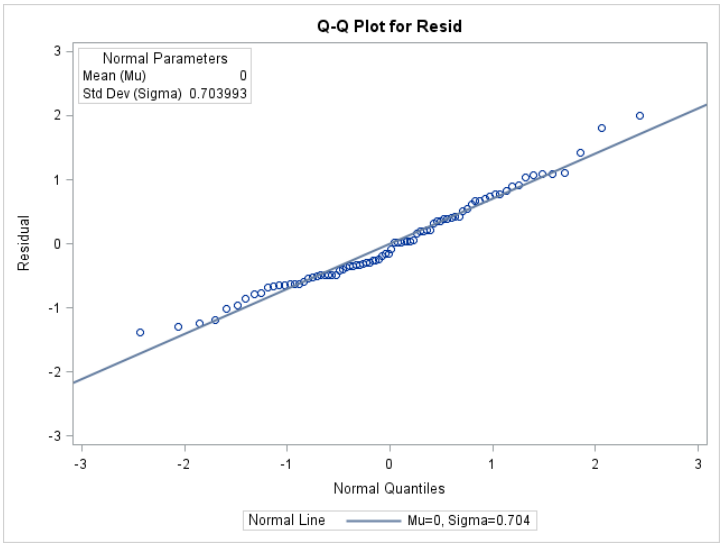


Figure 7. SCDNR red drum survey blacktip shark nominal (obscpue) and estimated (estcpue) indices with 95% confidence limits (LCL0, UCL0).

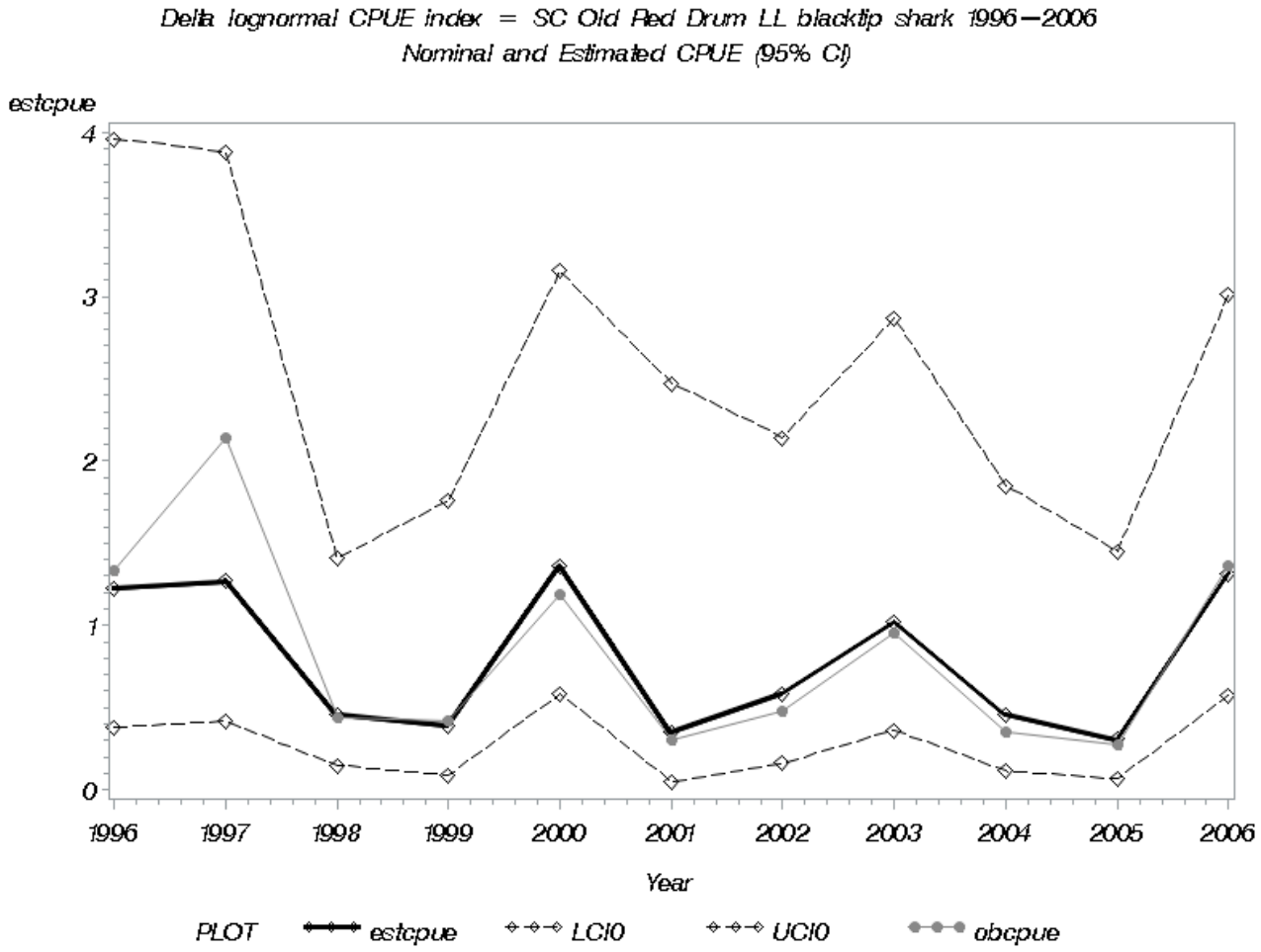
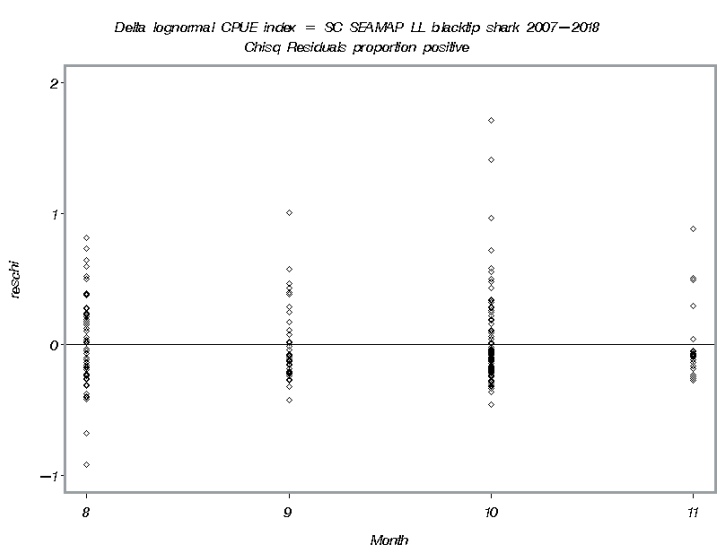
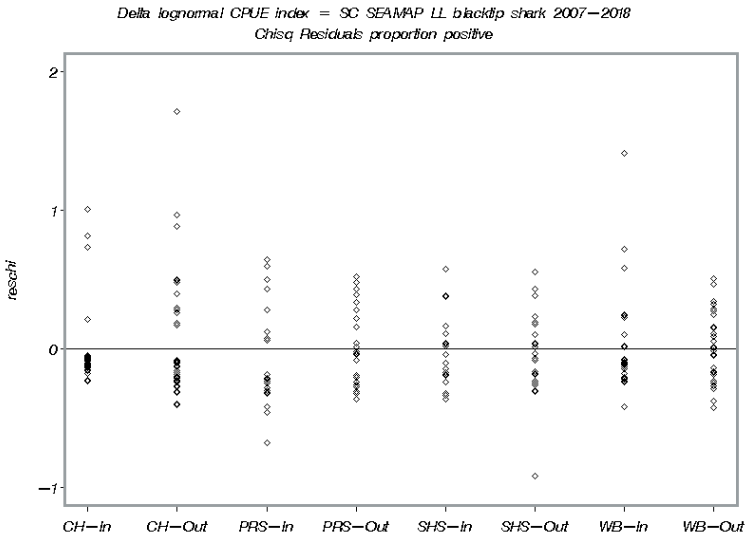
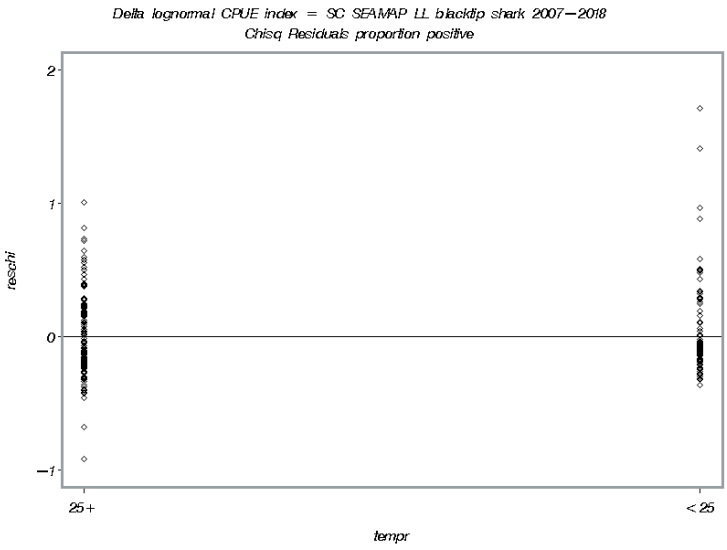


Figure 8. SCDNR SEAMAP longline survey blacktip shark model diagnostic plots for the binomial component.







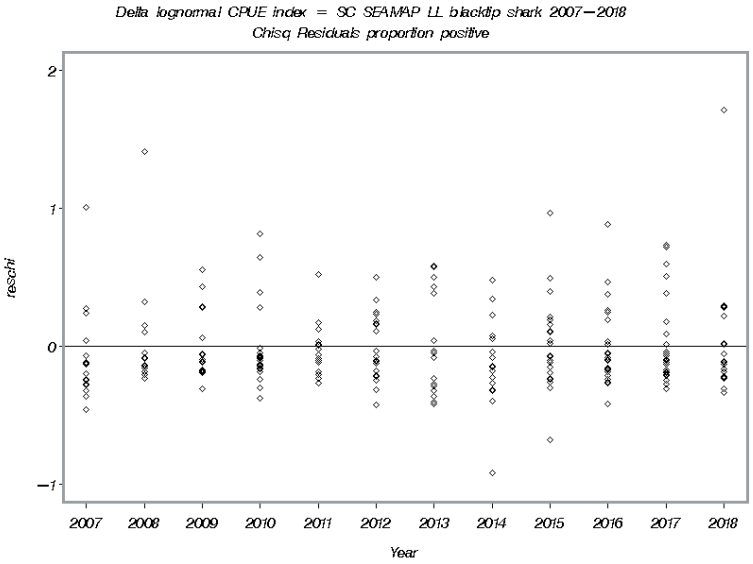


Figure 9. SCDNR SEAMAP longline survey blacktip shark model diagnostic plots for the lognormal component.

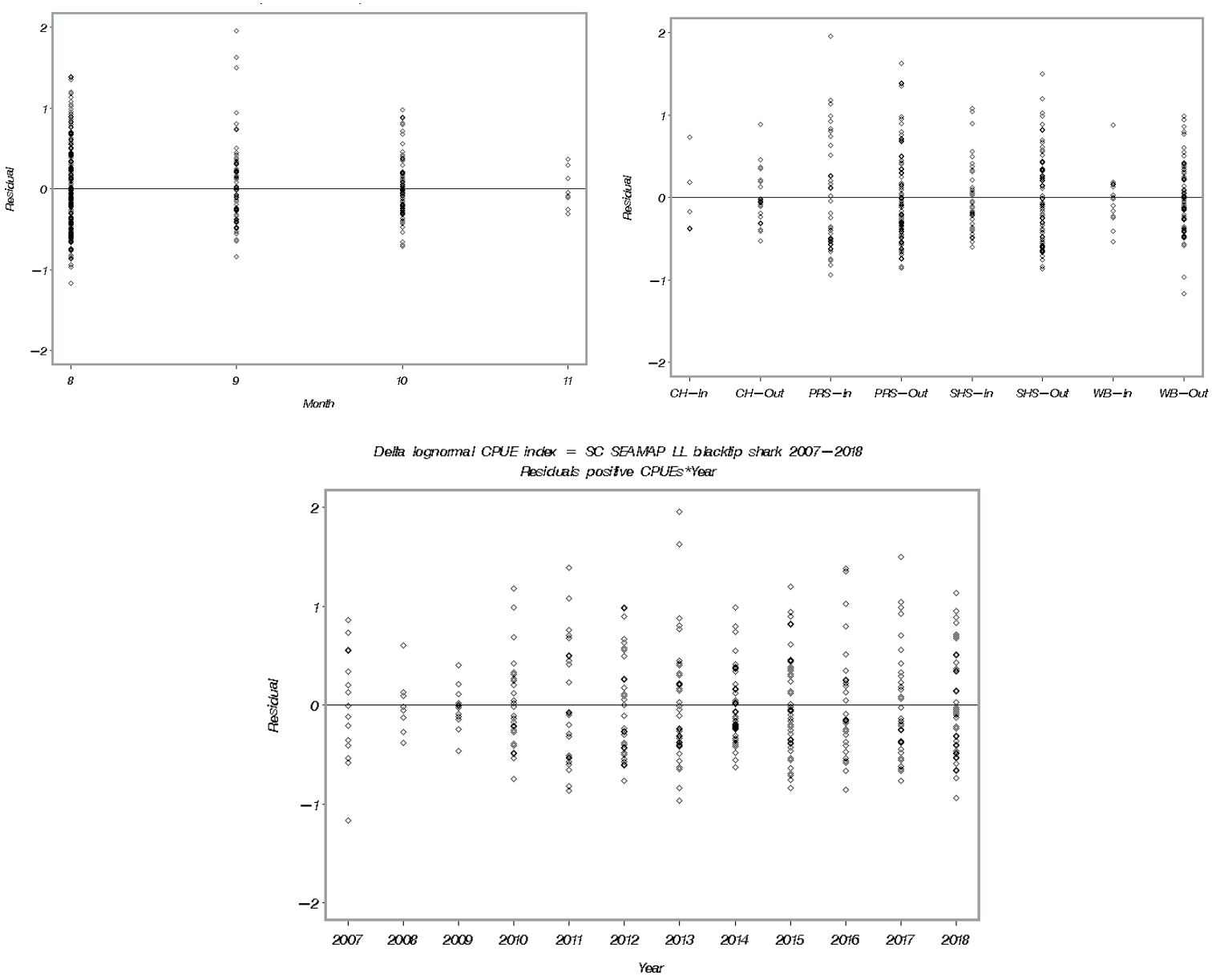


Figure 10. SCDNR SEAMAP longline survey blacktip shark nominal (obscpue) and estimated (estcpue) indices with 95% confidence limits (LCL0, UCL0).