Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the NOAA Cooperative Atlantic States Shark Pupping and Nursery longline survey

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SEDAR65-DW08

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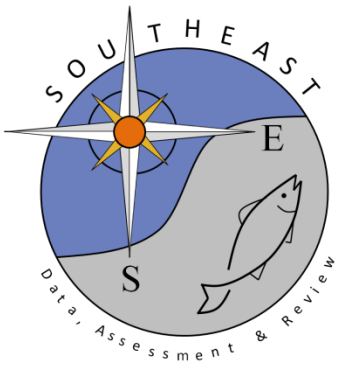

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SEDAR 65 DATA WORKSHOP DOCUMENT

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Summary

This document details the shark catches from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) longline surveys conducted in estuarine and nearshore waters from South Carolina to northern Florida. Catch per unit effort (CPUE) in number of sharks per 100 hook hours were used to examine total and young-of-the-year blacktip shark relative abundance from 2005-2018. The CPUE was standardized using 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 indices of abundance from the COASTSPAN longline survey show a slight decreasing trend overall in both total and YOY blacktip shark relative abundance across survey years with notable peaks in 2008 and 2013. A peak in 2013 was also seen in the South Carolina Department of Natural Resources (SCDNR) Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey (SEDAR65-DW11) and the SCDNR COASTSPAN long-gillnet survey (SEDAR65-DW07).

Introduction

In an effort to examine the use of South Carolina's, Georgia's and northern Florida's estuarine and nearshore waters as nursery areas for coastal shark species, personnel from the South Carolina Department of Natural Resources (SCDNR), Georgia Department of Natural Resources (GADNR), and the University of North Florida (UNF) in collaboration with the National Marine Fisheries Service's (NMFS) Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) program began sampling for sharks using longline and/or gillnet methods in several of their state's estuaries and nearshore waters. Sampling in South Carolina and, on a very limited basis, in Georgia began in 1998 by SCDNR and Savannah State University, respectively. GADNR took over Georgia sampling in 2000 and UNF began sampling in northern Florida in 2008. Exploratory sampling in the early years and a shift in spatial coverage in later years limit the start of the time series to 2005 for the analyses discussed in this working paper.

Methods

Sampling Gear and Data Collection

The COASTSPAN longline gear consists of 305 m of 0.64 cm braided nylon mainline and 50 gangions comprised of a 0.5 m, 91 kg test monofilament leader, size 120 stainless steel longline snap, 4/0 swivel and a 12/0 circle hook. Hooks are baited with Atlantic mackerel (*Scomber scombrus*) during SCDNR and UNF surveys and with squid (*Loligo sp*.) during GADNR surveys. Soak times varied, but averaged 30 minutes. At a minimum the set number, date, set and haul times, number of hooks, station location, depth, water temperature, and salinity were recorded for each set; and the species, sex, and fork length were recorded for each shark caught. Sharks were then tagged with either a NMFS rototag, jumbo 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 was used to examine the relative abundance of total and young-of the-year blacktip sharks. For the purposes of SEDAR 65, blacktip sharks larger than 66 cm FL (>1 year-old animals) were excluded from YOY analysis of the data. 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 analysis, factors considered as potential influences on the catch were year (2005-2018), month (June-August), depth (<5 m, 5+ m), salinity (<20 ppt, 20-24.9 ppt, 25-29.9 ppt, 30+ ppt), temperature (<20 degC, 20-24.9 degC, 25-29.9 deg C, 30+ degC), and area (Bulls Bay, St Helena, St. Simons, St. Andrew, Cumberland, and Nassau sound systems). The area factor is also expected to account for any survey effect between states. 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 948 blacktip sharks were caught during the 1883 longline sets from 2005 to 2018 included in these analyses for index development. The size range of blacktip sharks caught by year is displayed in Figure 1. The majority (88%) of the catch was YOY. The proportion of sets with positive catch (at least one blacktip shark caught) was 25% and with positive YOY catch (at least one YOY blacktip shark caught) was 22%. The stepwise construction of each model and the resulting statistics are detailed in Tables 1 and 3 for total blacktip sharks and YOY blacktip sharks, respectively. Model diagnostic plots reveal that the model fit is acceptable for both total blacktip sharks (Figures 2 and 3) and for YOY blacktip sharks (Figures 5 and 6). 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 4 and 7. Nominal and standardized CPUE results from the COASTSPAN longline survey show a slight decreasing trend overall in both total and YOY blacktip shark relative abundance across survey years with notable peaks in 2008 and 2013. A peak in 2013 was also seen in the SCDNR Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey (SEDAR65-DW11) and the SCDNR COASTSPAN long-gillnet survey (SEDAR65-DW07).

Table 1. Results of the stepwise procedure for development of the COASTSPAN longline survey catch rate model for total 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.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	589	965.6736	1.6395				
AREA	584	905.4805	1.5505	5.4285		60.19	<.0001
MONTH	587	919.0154	1.5656	4.5075		46.66	<.0001
SAL	586	934.7561	1.5951	2.7081		30.92	<.0001
TEMP	586	959.7837	1.6379	0.0976		5.89	0.1171
DEPTH	588	965.2432	1.6416	-0.1281		0.43	0.5518
YEAR	606	1000.2573	1.6506	-0.6770		19.73	0.1022
AREA +							
MONTH	582	859.1050	1.4761	9.9665	5.4590	46.38	<.0001
SAL	581	884.3307	1.5221	7.1607	2.6532	21.15	<.0001
AREA + MONTH							
SAL	579	843.8918	1.4575	11.1009	1.1345	15.21	0.0016
AREA + MONTH + SAL + YEAR	566	822.4901	1.4532	11.3632	0.2623	21.40	0.0654

FINAL MODEL: AREA + MONTH + SAL + YEAR

AIC 1528.4 **BIC** 1532.3 **(-2) Res LL** 1526.4

Type 3 Test of Fixed Effects for Final Model

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	AREA	MONTH	SAL	YEAR
	<.0001	<.0001	0.0060	0.2916
DF	5	2	3	13
CHI SQUARE	33.34	27.55	12.46	15.35

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	385	177.8159	0.4619				
AREA	380	161.8109	0.4258	7.8155		36.41	<.0001
YEAR	372	162.1582	0.4359	5.6289		35.58	0.0007
SAL	382	172.0289	0.4503	2.5114		12.77	0.0052
DEPTH	384	175.3167	0.4566	1.1474		5.46	0.0194
MONTH	383	175.1549	0.4573	0.9959		5.82	0.0545
TEMP	383	177.3001	0.4629	-0.2165		1.12	0.5708
AREA +							
YEAR	367	149.8193	0.4082	11.6259	5.9970	29.72	0.0052
SAL	377	159.3700	0.4227	8.4867	2.8578	5.87	0.1182
DEPTH	379	161.7051	0.4267	7.6207	1.9918	0.25	0.6153

FINAL MODEL: AREA + YEAR

AIC 817.9 **BIC** 821.8 **(-2) Res LL** 815.9

Type 3 Test of Fixed Effects for Final Model

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	AREA	YEAR
	<.0001	0.0011
DF	5	13
CHI SQUARE	34.43	34.22

Table 2. COASTSPAN longline survey total 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 hook 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	LCI	UCI	CV
2005	76	29	0.3816	3.2508	3.0231	1.7253	5.2971	0.2860
2006	62	18	0.2903	1.8815	1.5217	0.7305	3.1698	0.3796
2007	35	8	0.2286	0.9997	1.2054	0.4371	3.3241	0.5417
2008	48	15	0.3125	3.1985	3.4409	1.6522	7.1658	0.3795
2009	99	28	0.2828	1.3346	1.9428	1.1301	3.3400	0.2760
2010	116	40	0.3448	2.6814	2.0045	1.2283	3.2711	0.2486
2011	122	33	0.2705	1.3184	1.6024	0.9533	2.6936	0.2641
2012	114	41	0.3596	2.9433	2.6903	1.6950	4.2700	0.2341
2013	126	51	0.4048	2.6263	3.6962	2.4648	5.5429	0.2047
2014	72	26	0.3611	2.1670	1.9738	1.1055	3.5241	0.2960
2015	88	26	0.2955	1.3994	1.4657	0.8165	2.6309	0.2989
2016	133	37	0.2782	1.6902	1.7694	1.0892	2.8744	0.2462
2017	111	30	0.2703	1.8524	1.5851	0.9117	2.7559	0.2819
2018	134	27	0.2015	1.1227	1.0245	0.5628	1.8652	0.3064

Table 3. Results of the stepwise procedure for development of the COASTSPAN longline survey catch rate model for YOY 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.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	589	929.1779	1.5776				
AREA	584	843.9514	1.4451	8.3988		85.23	<.0001
MONTH	587	892.0702	1.5197	3.6701		37.11	<.0001
SAL	586	892.0488	1.5223	3.5053		37.13	<.0001
DEPTH	588	923.7841	1.5711	0.4120		5.39	0.0202
TEMP	586	922.1771	1.5737	0.2472		7.00	0.0719
YEAR	576	906.8898	1.5745	0.1965		22.29	0.0511
AREA +							
MONTH	582	806.6137	1.3859	12.1514	8.4812	37.34	<.0001
SAL	581	824.3839	1.4189	10.0596	6.3895	19.57	0.0002
AREA + MONTH							
SAL	579	792.5984	1.3689	13.2290	1.0776	14.02	0.0029
AREA + MONTH + SAL + YEAR	566	768.0858	1.3570	13.9833	0.7543	24.51	0.0267

FINAL MODEL: AREA + MONTH + SAL + YEAR

AIC 1565.2 **BIC** 1571.0 **(-2) Res LL** 1565.2

Type 3 Test of Fixed Effects for Final Model

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	AREA	MONTH	SAL	YEAR
	<.0001	<.0001	0.0125	0.1685
DF	5	2	3	13
CHI SQUARE	46.23	22.6	10.85	17.72

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	349	159.6645	0.4575				
AREA	344	146.6335	0.4263	6.8197		29.80	<.0001
YEAR	336	147.8159	0.4399	3.8470		26.99	0.0125
SAL	346	155.9619	0.4508	1.4645		8.21	0.0418
MONTH	347	156.8404	0.4520	1.2022		6.25	0.0440
DEPTH	348	158.2873	0.4548	0.5902		3.03	0.0816
TEMP	347	159.1511	0.4586	-0.2404		1.13	0.5691
AREA +							
YEAR	331	137.2701	0.4147	9.3552	5.5082	23.10	0.0405
MONTH	342	145.0351	0.4241	7.3005	3.4536	3.84	0.1469
SAL	341	144.9831	0.4252	7.0601	3.2131	3.96	0.2656

FINAL MODEL: AREA + YEAR

AIC 748.2 **BIC** 752.0 **(-2) Res LL** 746.2

Type 3 Test of Fixed Effects for Final Model

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	AREA	YEAR
	<.0001	0.0279
DF	5	12
CHI SQUARE	26.65	24.84

Table 4. COASTSPAN longline survey YOY 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 hook 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
2005	76	28	0.3684	3.1531	2.8189	1.5563	5.1057	0.3037
2006	62	17	0.2742	1.7565	1.4128	0.6508	3.0673	0.4026
2007	35	8	0.2286	0.9997	1.2135	0.4327	3.4034	0.5519
2008	48	15	0.3125	2.6985	2.8834	1.3607	6.1100	0.3891
2009	99	24	0.2424	1.1920	1.8817	1.0330	3.4277	0.3067
2010	116	33	0.2845	2.3557	1.7531	1.0003	3.0725	0.2862
2011	122	30	0.2459	1.2275	1.5969	0.9172	2.7803	0.2827
2012	114	39	0.3421	2.8135	2.6555	1.6352	4.3124	0.2460
2013	126	49	0.3889	2.3320	3.4398	2.2408	5.2801	0.2168
2014	72	24	0.3333	2.0364	1.8919	1.0176	3.5176	0.3177
2015	88	17	0.1932	0.9000	0.8971	0.4210	1.9117	0.3923
2016	133	33	0.2481	1.5775	1.6699	0.9825	2.8382	0.2699
2017	111	29	0.2613	1.8187	1.6069	0.9033	2.8587	0.2941
2018	134	26	0.1940	1.1058	1.0313	0.5533	1.9220	0.3190

Figure 1. Fork lengths (cm) of blacktip sharks caught during the COASTSPAN longline survey from 2005-2018

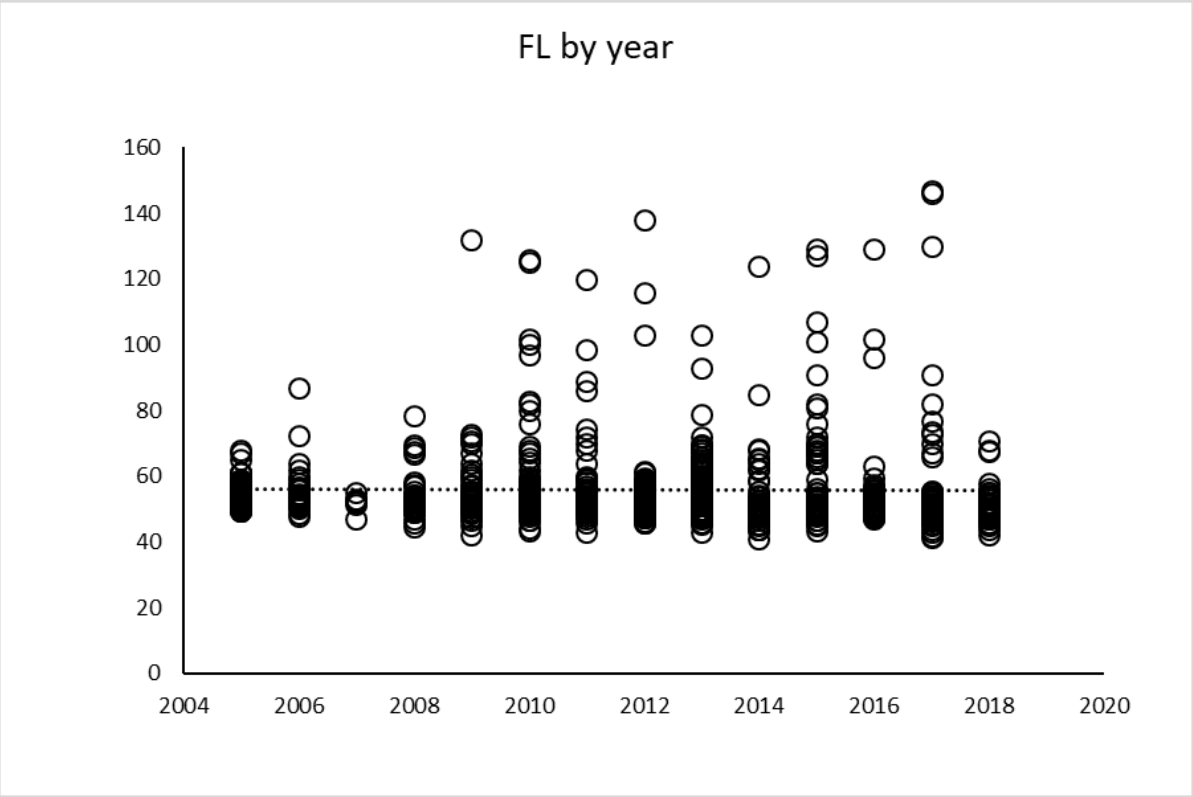
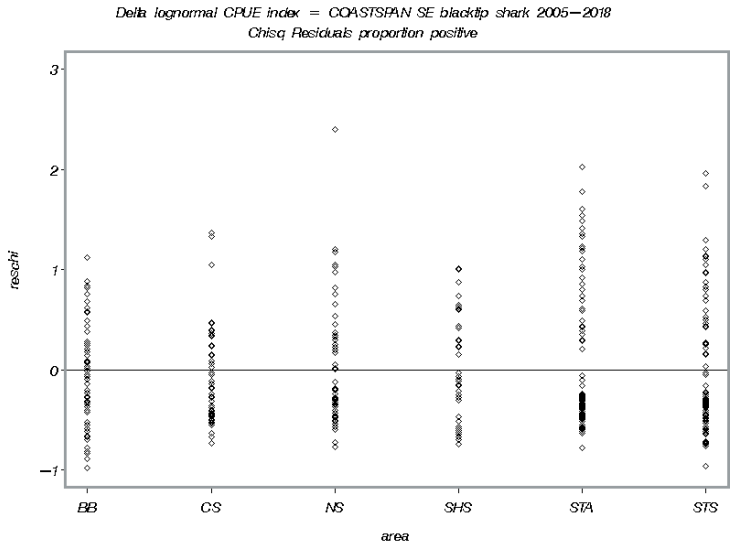
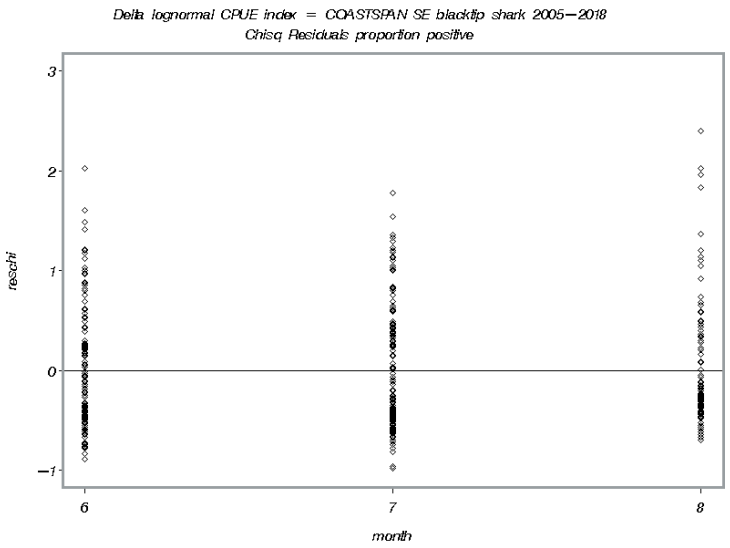
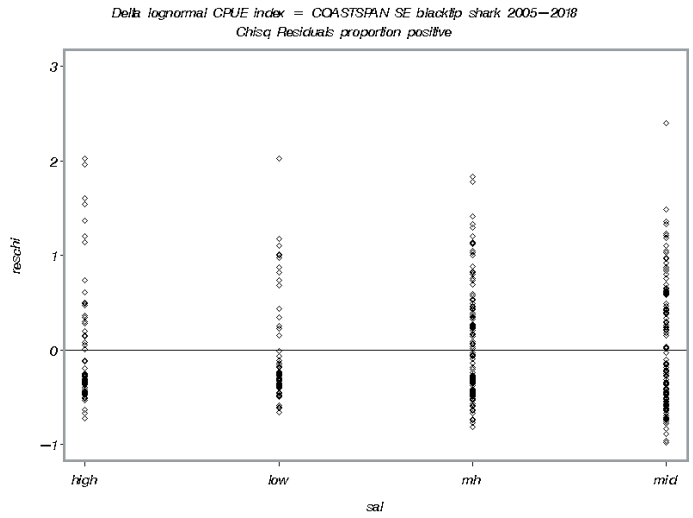


Figure 2. Total blacktip shark model diagnostic plots for the binomial component.







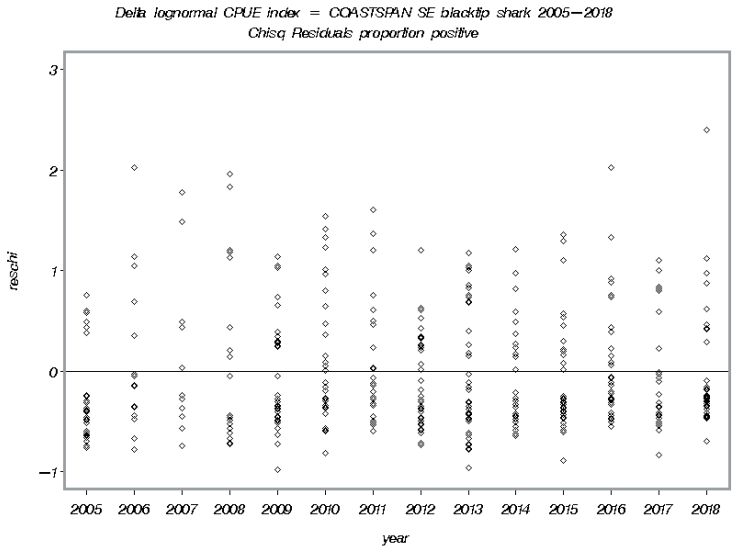


Figure 3. Total blacktip shark model diagnostic plots for lognormal component.

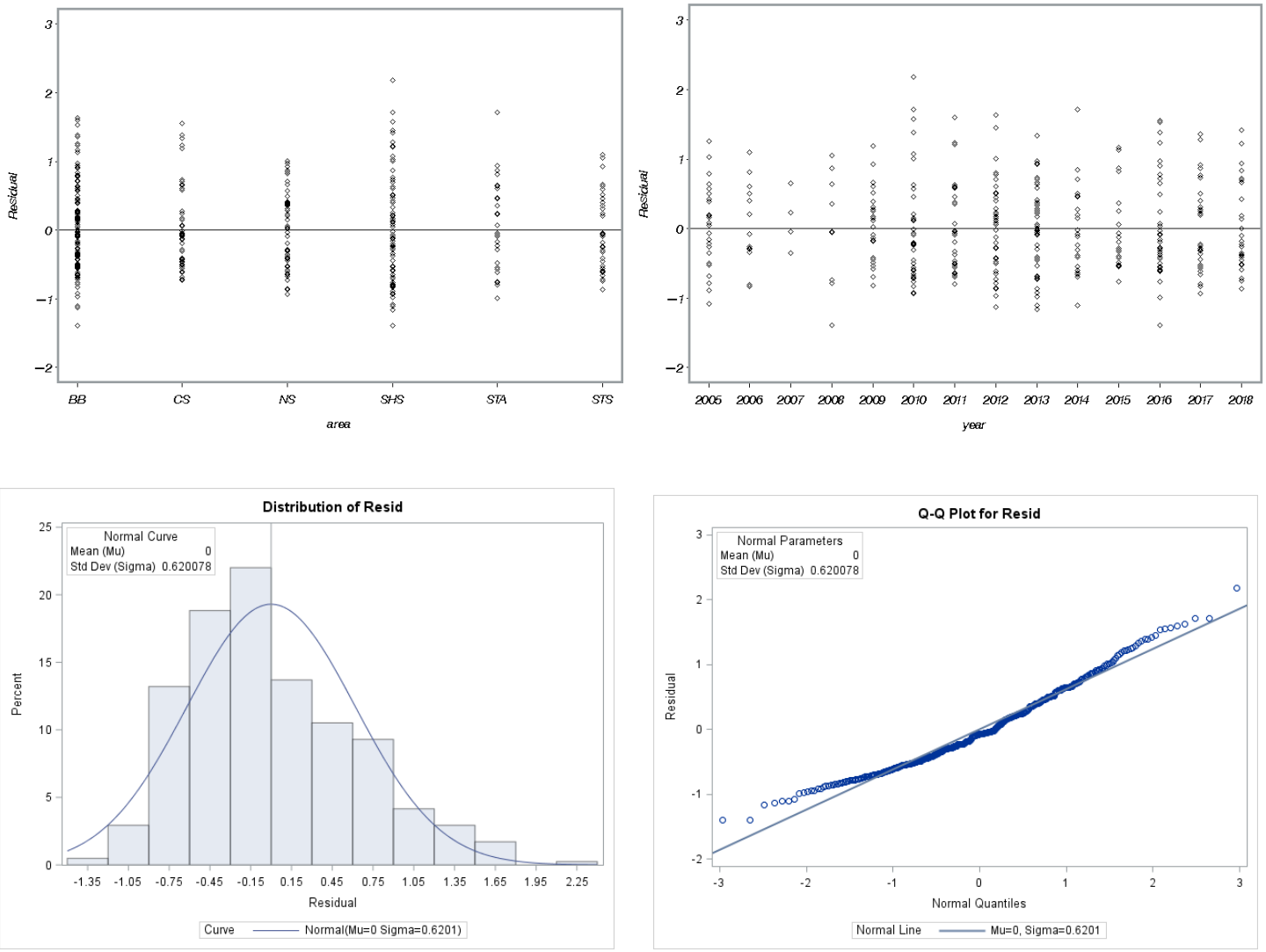


Figure 4. COASTSPAN longline survey total blacktip shark nominal (obcpue) and estimated (estcpue) indices with 95% confidence limits (LCI0), UCI0).

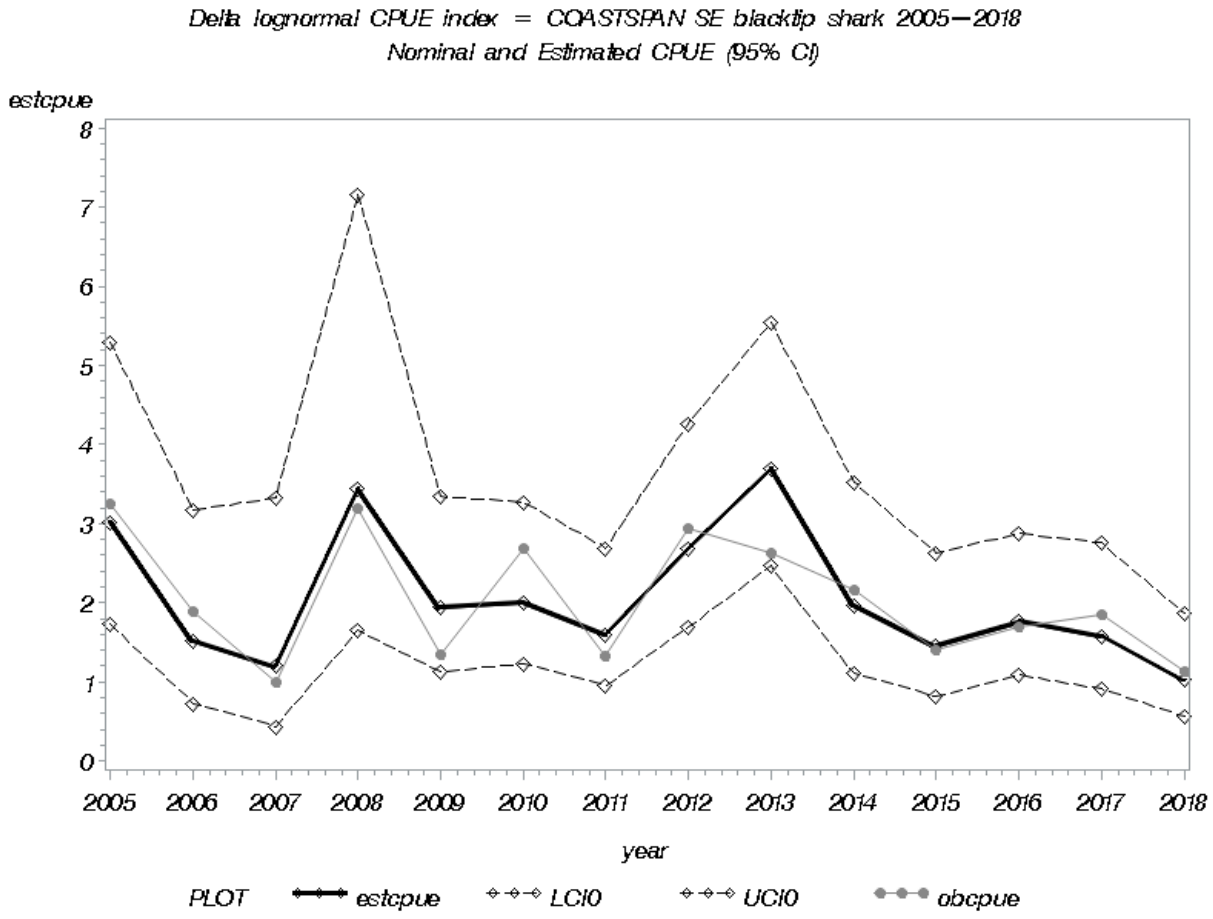


Figure 5. YOY blacktip shark model diagnostic plots for the binomial component.

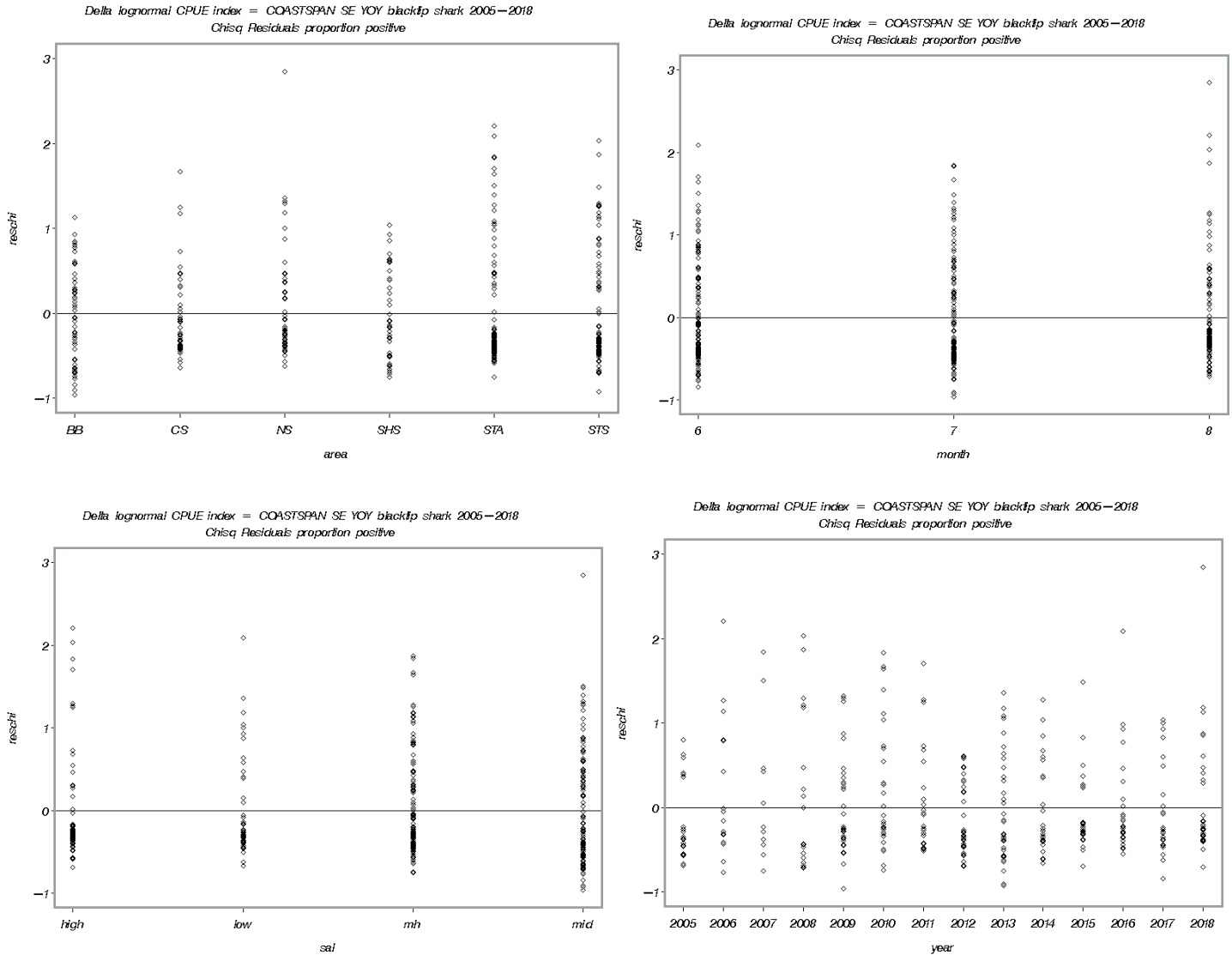


Figure 6. YOY blacktip shark model diagnostic plots for the lognormal component.

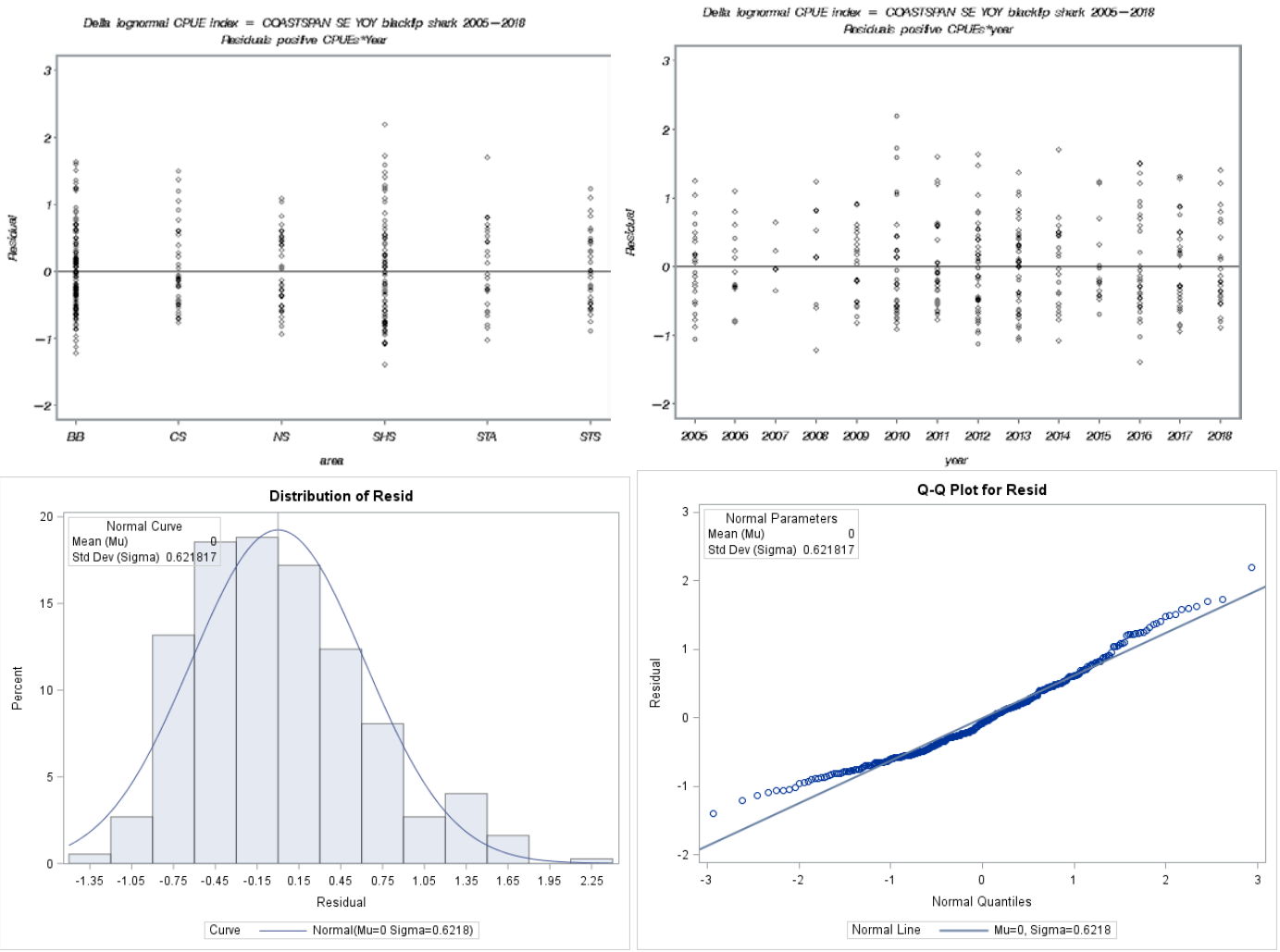


Figure 7. COASTSPAN longline survey YOY blacktip shark nominal (obcpue) and estimated (estcpue) indices with 95% confidence limits (LCI0), UCI0).