Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery long-gillnet survey.

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SEDAR65-DW07

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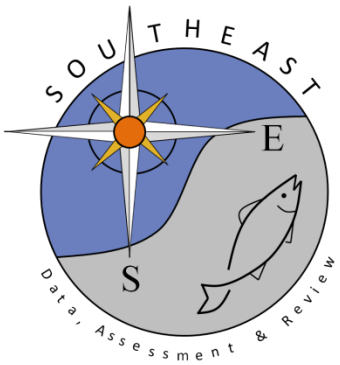

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SEDAR 65 DATA WORKSHOP DOCUMENT

Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the South Carolina Department of Natural Resources, Cooperative Atlantic States Shark Pupping and Nursery long-gillnet survey

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Summary

This document details blacktip shark catches from the South Carolina Department of Natural Resources (SCDNR), Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) long-gillnet survey (2001-2018). Catch per unit effort (CPUE) in number of sharks per net hour were used to examine total and young-of-the-year (YOY) blacktip shark relative abundance in South Carolina's estuarine waters. 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. Nominal and standardized CPUE results from the COASTSPAN long-gillnet survey indicate a slight increasing trend overall in total and YOY blacktip shark relative abundance across survey years with a notable peak in 2013. This peak was also seen in the SCDNR Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey (SEDAR65-DW11) and, not as pronounced, in the COASTSPAN longline survey (SEDAR65-DW08). For both long-gillnet survey time series, the 2006 index value was estimated using only the lognormal component of the model because the proportion of positive catch sets was 100% for that year.

Introduction

In an effort to examine the use of South Carolina's estuarine waters as nursery areas for coastal shark species the South Carolina Department of Natural Resources (SCDNR) Marine Resources Division, in collaboration with the National Marine Fisheries Service's (NMFS) Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Survey began sampling for sharks using longline and gillnet methods in several estuaries within South Carolina in 1998.

Methods

Sampling gear and data collection

SC COASTSPAN estuarine sampling locations were selected in the lower reaches of estuaries in depths which would facilitate the deployment and retrieval of gillnets. All gillnet sampling occurred inside of inlets and sampling locations varied with regard to distance from nearshore waters. Sampling was conducted primarily from April through October with the majority of the effort occurring between May and September.

Sampling gear and data collection

The SC COASTSPAN long gillnet survey used an anchored gillnet, 3 m deep and constructed of #177 monofilament twine with a stretched mesh of 10.3 cm. This net was approximately 230 m in length. The net was set in <4 m of water adjacent to shorelines and inspected for catch at approximately 20-minute intervals to reduce mortality. Station location, water temperature, salinity, dissolved oxygen set and pickup time and time of day were recorded for each sex. The sex, 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 net hour was used to examine the relative abundance of young-of the-year (YOY) and total 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 long-gillnet survey data. Since the net is set on station and inspected (hauled) multiple times and re-set to reduce bycatch before the final haulback, there were records of short soak times (<5 minutes). This occurs when the end set gillnet anchor was deployed and then the net was immediately retrieved at the start set anchor to inspect the net. To avoid unreasonably high catch rates due to these short soak times, all sets conducted consecutively at the same station were grouped and the combined catch and soak times were considered a single set. This resulted in no zero catch sets for the year 2006. 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 the catch were year (2001-2018), month (May-August), salinity (<28 ppt, ≥28 ppt), temperature (<25 deg C, ≥25 deg C) and area (stations located in Bulls Bay and North Edisto estuarine waters). 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. The year 2006 index value was only based on the lognormal component since the proportion of positive catch sets was 100% for that year.

Results

A total of 444 blacktip sharks were caught during the 186 gillnet sets from 2001 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 (79%) of the catch was YOY. The proportion of sets with positive catch (at least one blacktip shark caught) was 54% and with positive YOY catch (at least one YOY blacktip shark caught) was 47%. 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 long-gillnet survey indicate a slight increasing trend overall in both total and YOY blacktip shark relative abundance across survey years with a notable peak in 2013. This peak was also seen in the SCDNR Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey (SEDAR65-DW11) and, not as pronounced, in the COASTSPAN longline survey (SEDAR65-DW08). For both long-gillnet survey time series the 2006 index value was estimated using only the lognormal component of the model because the proportion of positive catch sets was 100% for that year.

Table 1. Results of the stepwise procedure for development of the SCDNR COASTSPAN large-gillnet 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	145	209.2222	1.4429				
area	144	198.8285	1.3808	4.3038		10.39	0.0013
sal	144	200.0845	1.3895	3.7009		9.14	0.0025
month	141	197.1345	1.3981	3.1049		12.09	0.0167
temp	144	204.9063	1.4230	1.3792		4.3200	0.0378
year	128	190.0852	1.4850	-2.9177		19.14	0.3207
area +							
month	140	182.6552	1.3047	9.5779	5.8771	16.17	0.0028
temp	143	193.2131	1.3511	6.3622	3.2573	5.62	0.0178
sal	143	195.7616	1.3690	5.1216	0.8178	3.07	0.0799
year	127	177.2783	1.3959	3.2573	1.8782	21.55	0.2026
area + month							
temp	139	181.4536	1.3054	9.5294	-0.0485	1.20	0.2730

FINAL MODEL: area + month + year

AIC 476.0 **BIC** 478.5 **(-2) Res LL** 474.0

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	area	month	year
DF	1	4	16
CHI SQUARE	12.70	13.50	10.07

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	93	118.9598	1.2791				
year	77	71.2430	0.9252	27.6679		48.19	<.0001
area	92	95.7166	1.0404	18.6616		20.44	<.0001
month	89	108.8751	1.2233	4.3624		8.33	0.0803
temp	92	115.8757	1.2595	1.5323		2.47	0.1161
sal	92	118.8272	1.2916	-0.9772		0.10	0.7460
year +							
area	76	63.8643	0.8403	34.3054	6.6375	10.28	0.0013

FINAL MODEL: year + area

AIC 249.2 **BIC** 251.6 **(-2) Res LL** 247.2

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	year	area
DF	17	1
CHI SQUARE	35.11	7.79

Table 2. SCDNR COASTSPAN large-gillnet total blacktip shark analysis number of model observations per year (n obs), number of positive model observtions per year (obs pos), proportion of positive model observations per year (obs ppos), nominal cpue as sharks per 100 hook hours (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
2001	14	10	0.7143	0.6216	0.7001	0.3643	1.3457	0.3356
2002	13	4	0.3077	0.2435	0.2226	0.0675	0.7339	0.6537
2003	15	9	0.6000	1.2949	0.8146	0.3962	1.6750	0.3725
2004	3	1	0.3333	0.1961	0.1451	0.0192	1.0944	1.3325
2005	11	6	0.5455	0.8446	0.9064	0.3752	2.1895	0.4633
2006	6	6	1.0000	0.7503	1.0225	0.6374	1.6403	0.3704
2007	10	4	0.4000	0.3896	0.4904	0.1656	1.4525	0.5854
2008	9	4	0.4444	0.2763	0.5644	0.2060	1.5461	0.5376
2009	6	4	0.6667	0.7290	0.7493	0.3019	1.8594	0.4790
2010	7	3	0.4286	0.3355	0.6152	0.2081	1.8185	0.5843
2011	5	2	0.4000	0.1290	0.2755	0.0719	1.0558	0.7552
2012	9	2	0.2222	1.1990	0.8465	0.1807	3.9654	0.9029
2013	13	7	0.5385	4.4720	3.8455	1.7277	8.5591	0.4166
2014	8	4	0.5000	1.0001	0.8915	0.3269	2.4313	0.5349
2015	13	5	0.3846	0.4187	0.4001	0.1494	1.0719	0.5242
2016	11	2	0.1818	0.1421	0.1181	0.0253	0.5506	0.8992
2017	13	6	0.4615	2.4878	1.3561	0.5318	3.4578	0.4949
2018	16	7	0.4375	1.1004	0.9674	0.4054	2.3086	0.4563

Table 3. Results of the stepwise procedure for development of the SCDNR COASTSPAN large-gillnet 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	145	212.2942	1.4641				
area	144	201.0624	1.3963	4.6308		11.23	0.0008
month	141	199.8969	1.4177	3.1692		12.40	0.0146
temp	143	191.4938	1.3391	8.5377		9.57	0.0020
sal	144	208.1764	1.4457	1.2567		4.12	0.0424
year	128	188.8508	1.4754	-0.7718		23.44	0.1354
area +							
month	140	184.8409	1.3203	9.8217	8.5650	16.22	0.0027
temp	143	193.2131	1.3511	7.7181	4.5489	5.62	0.0178
sal	143	195.7616	1.3690	6.4955	1.8646	3.07	0.0799
year	127	177.2783	1.3959	4.6582	-3.8795	21.55	0.2026
area + month							
temp	139	181.4536	1.3054	10.8394	1.0177	1.20	0.2730

FINAL MODEL: area + month + year

AIC 473.6 **BIC** 476.1 **(-2) Res LL** 471.6

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	area	month	year
DF	1	4	16
CHI SQUARE	13.64	14.56	11.78

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	80	102.8826	1.2860				
year	64	58.7102	0.9173	28.6703		45.44	0.0001
area	79	82.9573	1.0501	18.3437		17.44	<.0001
month	76	94.4062	1.2422	3.4059		6.96	0.1378
temp	79	99.5915	1.2607	1.9673		2.63	0.1046
sal	79	102.8695	1.3021	-1.2519		0.10	0.9193
year + area	63	53.6158	0.8510	33.8258	5.1555	7.35	0.0067

FINAL MODEL: year + area

AIC 211.2 **BIC** 213.4 **(-2) Res LL** 209.2

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	year	area
DF	17	1
CHI SQUARE	32.03	5.33

Table 4. SCDNR COASTSPAN large-gillnet YOY blacktip shark analysis number of model observations per year (n obs), number of positive model observtions per year (obs pos), proportion of positive model observations per year (obs ppos), nominal cpue as sharks per 100 hook hours (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
2001	14	10	0.7143	0.9639	0.7976	0.4578	1.3896	0.2830
2002	13	6	0.4615	0.3022	0.3089	0.1355	0.7041	0.4301
2003	15	9	0.6000	1.4017	0.9009	0.4838	1.6775	0.3185
2004	3	1	0.3333	0.1961	0.1496	0.0232	0.9647	1.1760
2005	11	6	0.5455	0.8446	0.8355	0.3852	1.8121	0.4021
2006	6	6	1.0000	0.8273	1.1390	0.7112	1.8244	0.3691
2007	10	5	0.5000	0.4225	0.4859	0.2162	1.0919	0.4220
2008	9	4	0.4444	0.2763	0.5520	0.2331	1.3072	0.4518
2009	6	5	0.8333	1.0415	1.0722	0.5304	2.1677	0.3632
2010	7	4	0.5714	0.5966	1.0557	0.4731	2.3556	0.4180
2011	5	3	0.6000	0.3829	0.7263	0.2947	1.7898	0.4749
2012	9	2	0.2222	1.4750	0.9271	0.2349	3.6582	0.7757
2013	13	7	0.5385	4.5857	3.6840	1.8363	7.3910	0.3590
2014	8	4	0.5000	1.4694	1.2765	0.5307	3.0705	0.4608
2015	13	8	0.6154	0.6755	0.7070	0.3921	1.2748	0.3013
2016	11	4	0.3636	0.8160	0.6067	0.2293	1.6057	0.5169
2017	13	6	0.4615	2.6637	1.3203	0.5886	2.9618	0.4210
2018	16	9	0.5625	1.4507	1.4201	0.7675	2.6277	0.3151

Figure 1. Fork lengths (cm) of blacktip sharks caught during the SCDNR COASTSPAN long-gillnet survey from 2001-2018.

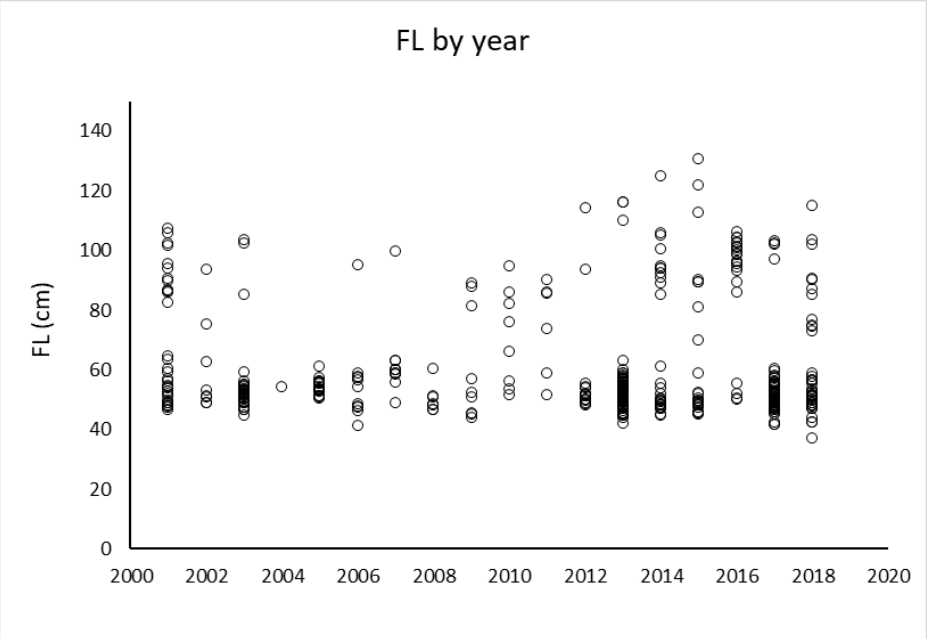


Figure 2. Total blacktip shark model diagnostic plots for the binomial component.

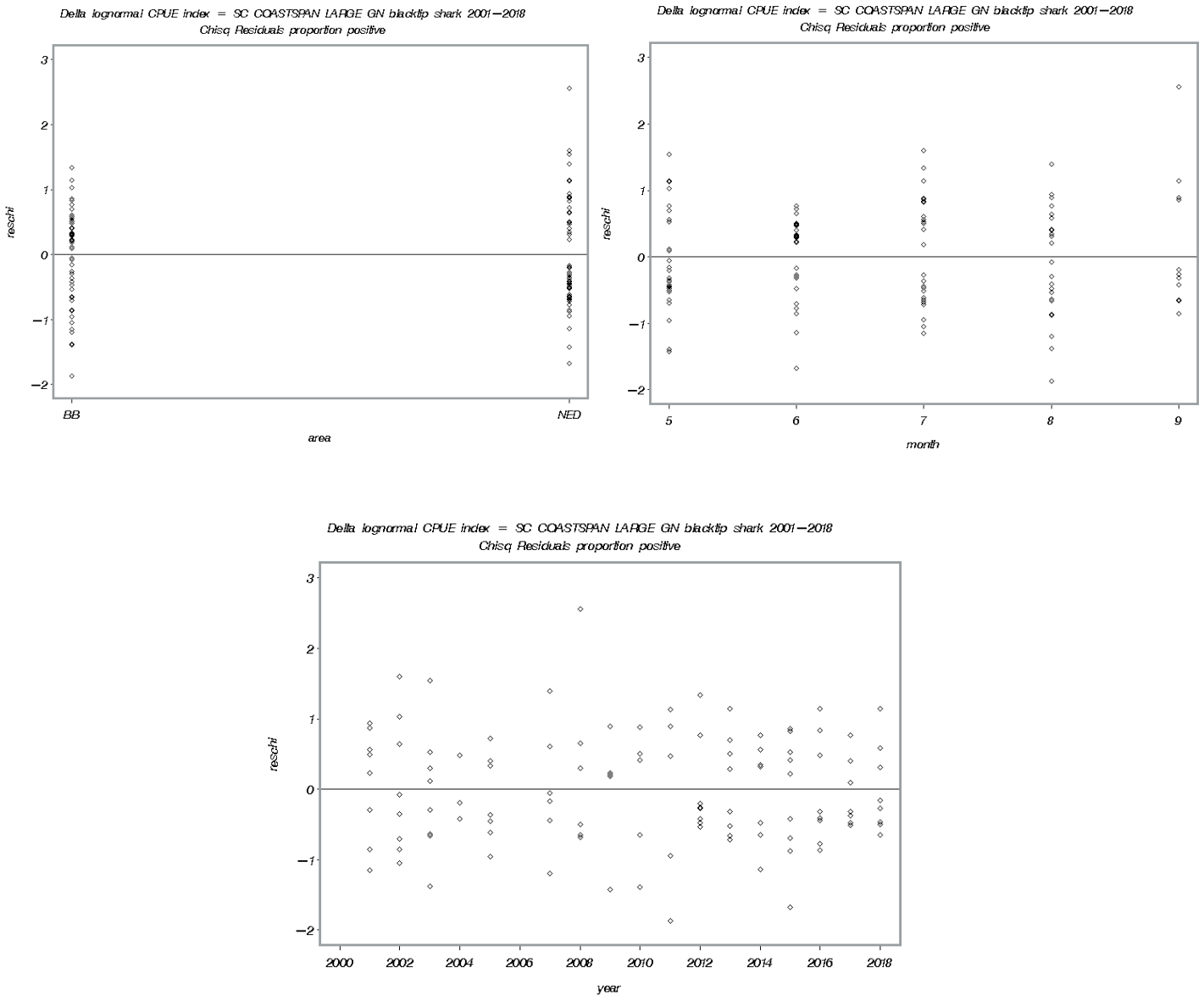
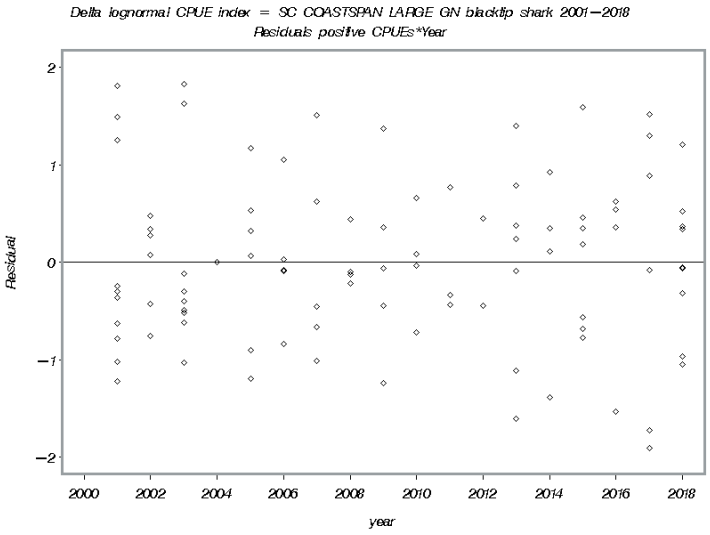
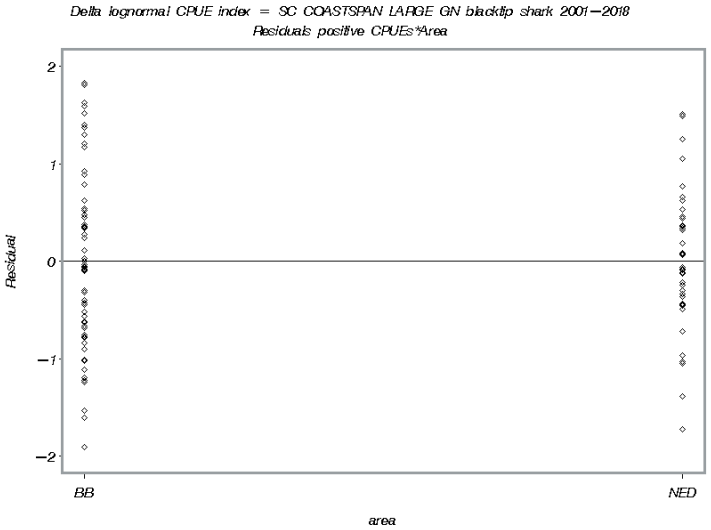
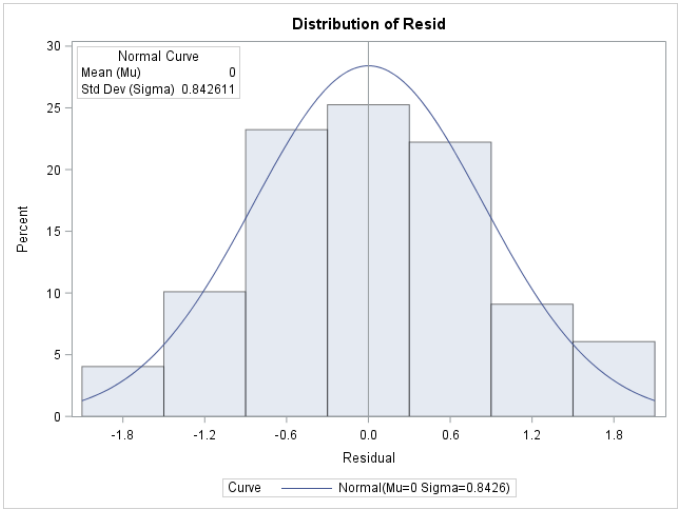


Figure 3. Total blacktip shark model diagnostic plots for the lognormal component.







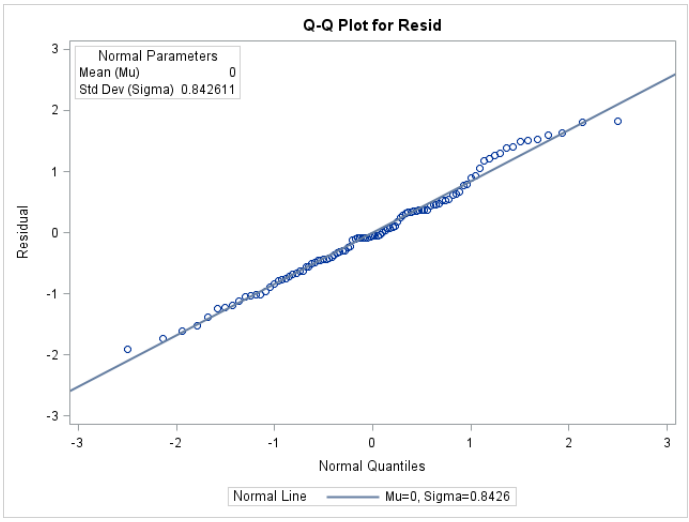


Figure 4. SCDNR COASTSPAN large-gillnet total blacktip shark nominal (obscpue) and estimated (estcpue) indices with 95% confidence limits (LCI0, UCI0).

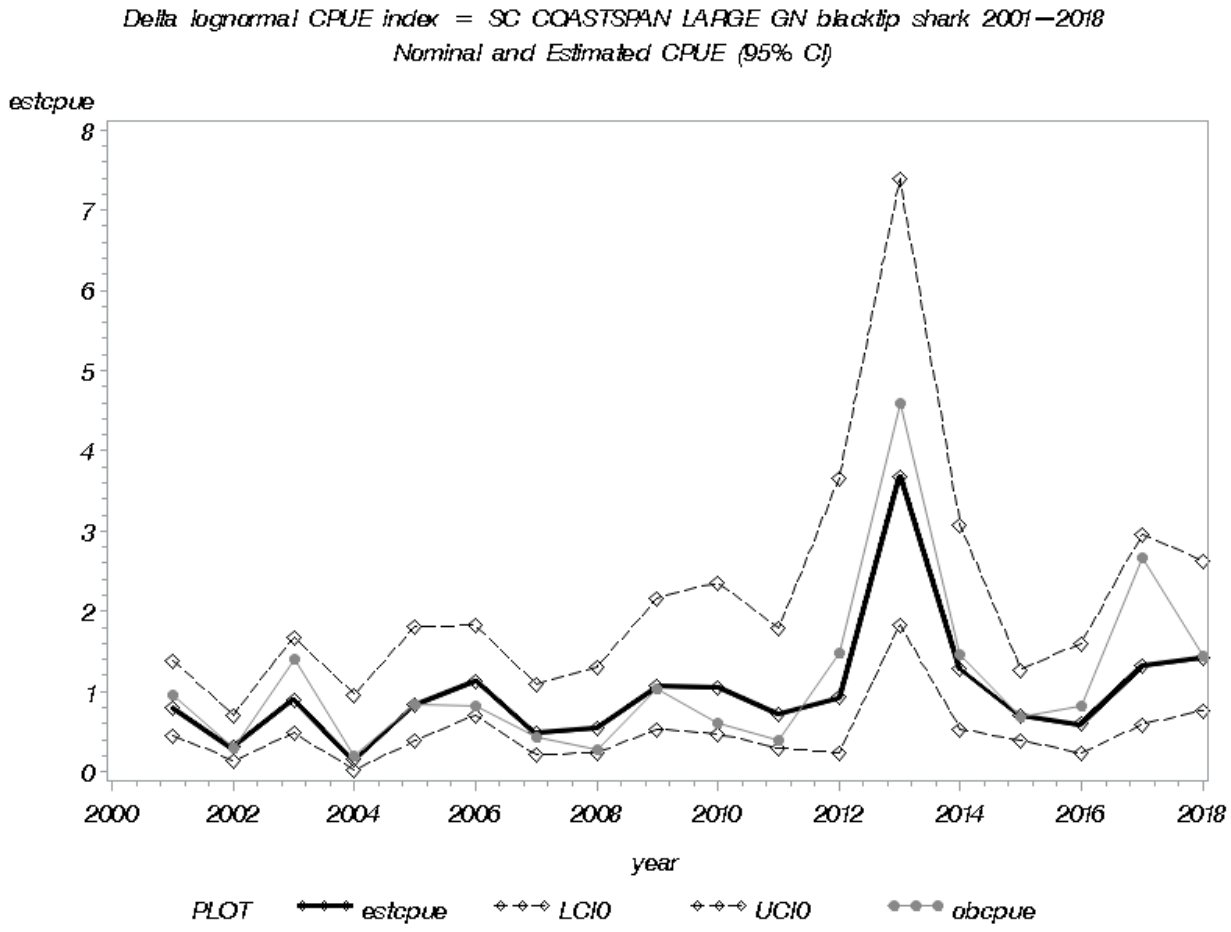
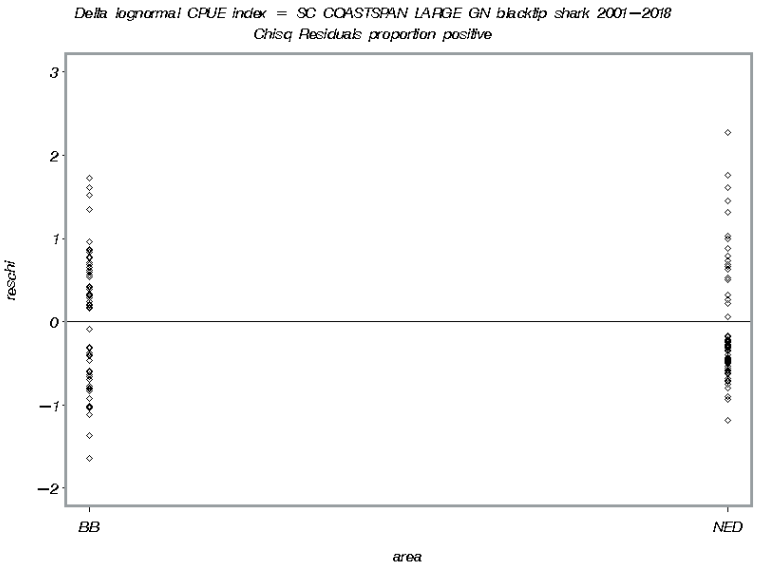
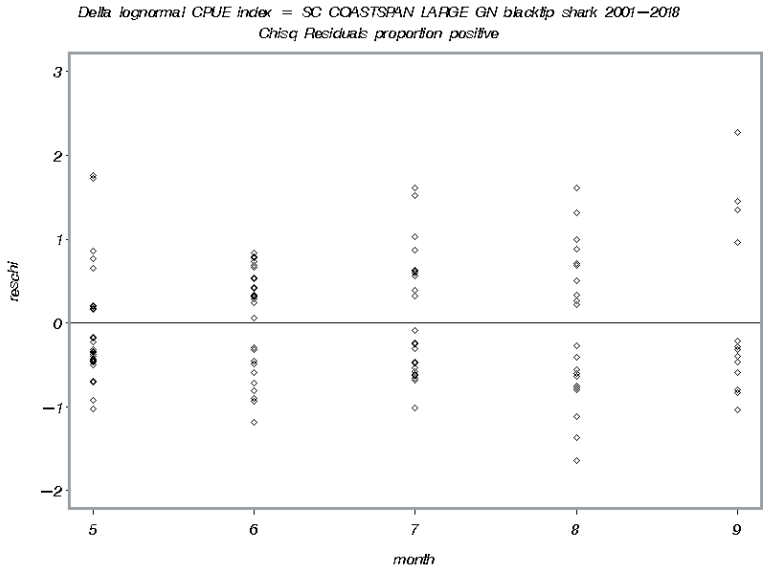


Figure 5. YOY blacktip shark model diagnostic plots for the binomial component.





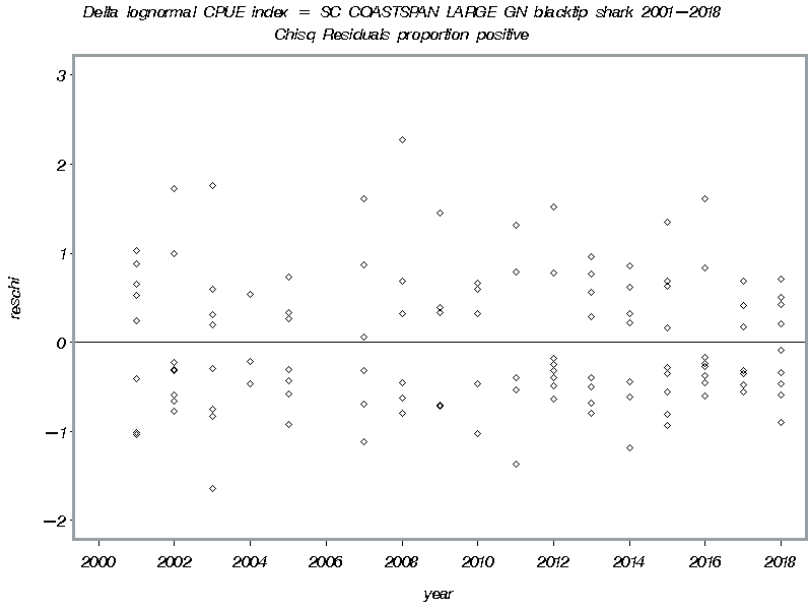
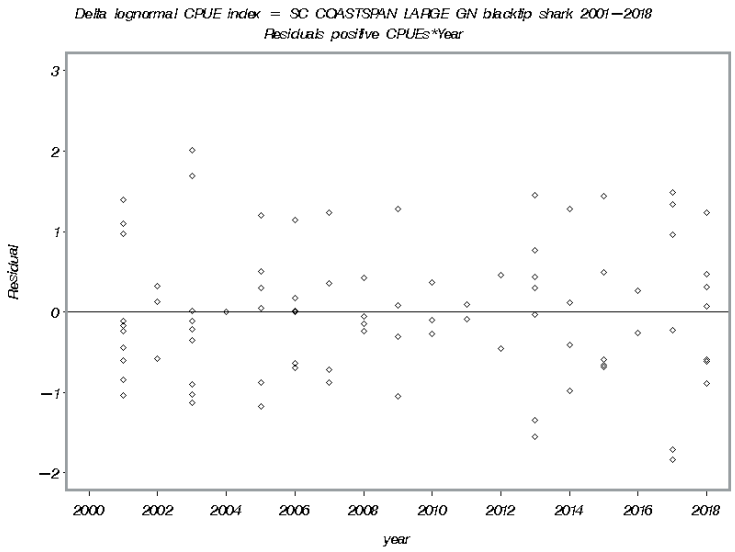
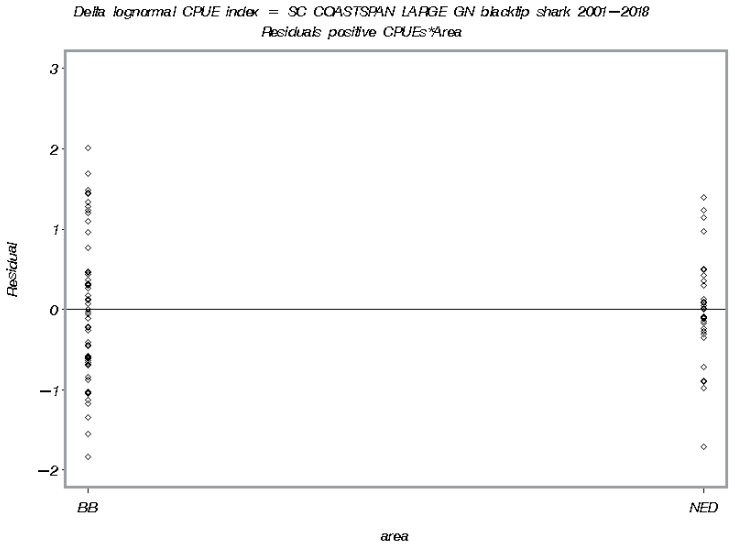
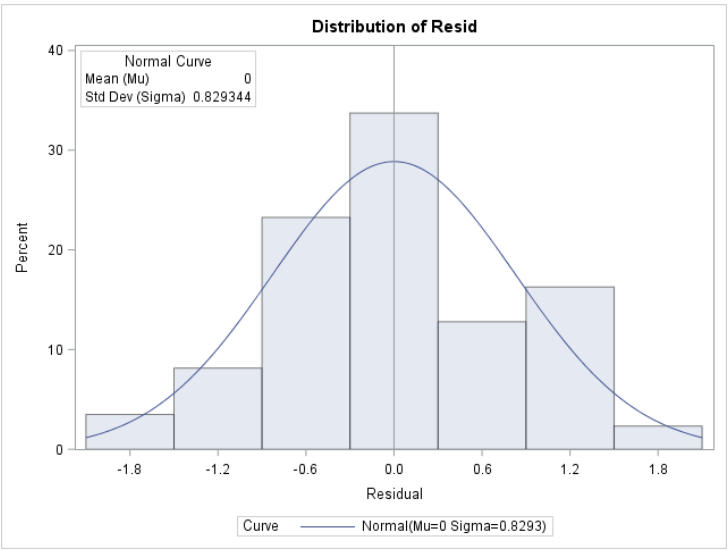


Figure 6. YOY blacktip shark model diagnostic plots for the lognormal component







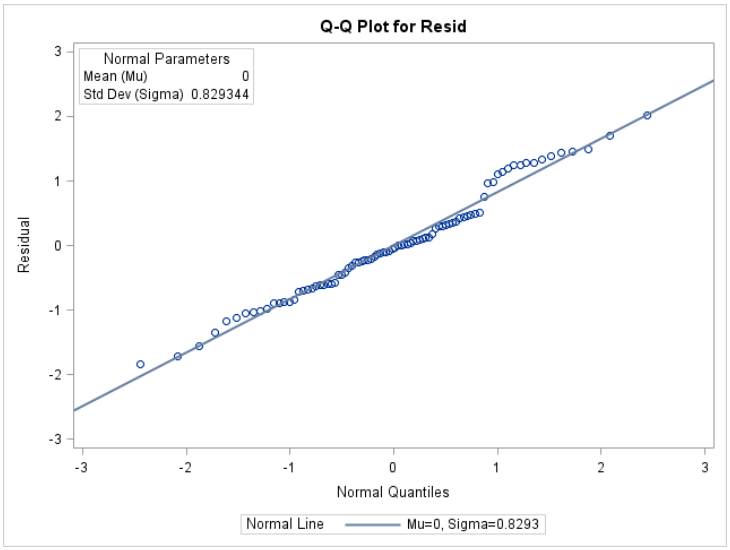


Figure 7. SCDNR COASTSPAN large-gillnet YOY blacktip shark nominal (obscpue) and estimated (estcpue) indices with 95% confidence limits (LCI0, UCI0).