Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the Georgia Department of Natural Resources, Southeast Area Monitoring and Assessment Program longline survey

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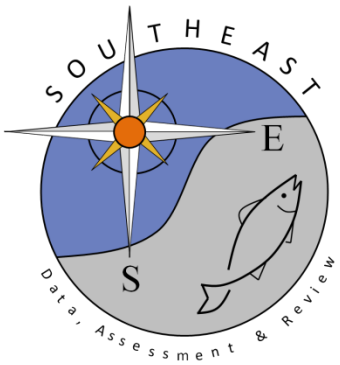

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SEDAR 65 DATA WORKSHOP DOCUMENT

Standardized catch rates of blacktip sharks, *Carcharhinus limbatus*, from the Georgia Department of Natural Resources, Southeast Area Monitoring and Assessment Program longline survey

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Summary

This document details the shark catches from the Georgia Department of Natural Resources (GADNR) Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey conducted in Georgia and northern Florida's nearshore and offshore waters from 2007-2018. Catch per unit effort (CPUE) in number of sharks per 100 hook hours were used to examine blacktip shark relative abundance in Georgia's coastal waters. Differences in bait and hook type were found to have a significant effect on blacktip shark catches, but were not able to be accounted for in the model since the differences did not overlap within years. 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 resulting relative abundance has an overall decreasing trend due to the high first year and is likely influenced by the change in bait and hook type. Highest estimate is in 2007, the only year where both mixed bait sets and mixed hook sets were used. Following this year there is a variable but overall increasing trend from 2008 to 2015 when the bait and hook type are held constant (squid bait, mixed hooks). There is another dip in 2016 when small hooks are removed but mixed baits are returned. The trend increases again for the remainder of the time series while the mixed baits and large hooks are held constant from 2016 to 2018. Running the analyses again without 2007 produces an overall increasing trend but retains the variability.

Introduction

In 2006 a pilot study to work out the logistics of a Georgia Department of Natural Resources (GADNR) Southeast Area Monitoring and Assessment Program (SEAMAP) longline survey was conducted. The objectives of this survey are to develop a state specific sampling protocol that provides a fisheries independent index of abundance for adult red drum, to sample adult red drum and develop information on catch per unit effort (CPUE) and size, to collect migratory and stock identification data on adult red drum *Sciaenops ocellatus* to evaluate age composition and reproductive status of red drum <90 cm total length, and to disseminate accomplishments and results to the Atlantic States Marine Fisheries Commission (ASMFC) and the National Marine Fisheries Service (NMFS) for inclusion in stock assessment efforts. The GADNR SEAMAP survey gear also targets multiple coastal shark species. The survey design was finalized and sampling began in 2007.

Methods

Sampling Gear and Data Collection

A stratified random sampling approach was used to select sampling locations. General sampling sites were selected based on scientific expertise and known historical areas of high abundance for red drum. Strata are defined spatially and temporally. There are three spatial strata: inshore waters, nearshore waters, and offshore artificial reefs (Figure 1). Temporal stratification proportionally allocates effort between the inshore/nearshore and offshore areas over the duration of the sampling season and mirrors the offshore migration of the adult red drum. Starting in September 75% of the effort is focused in the nearshore waters and 25% is focused in the offshore. In October the allocation shifts to 50% nearshore and 50% offshore. In November the shift becomes 25% / 75%, ending at 0% / 100% in December. Sampling units are defined as 0.5 by 0.5 nautical mile quadrats which overlay the sampling area described above. Initially a total of 25 stations were sampled from April through August off coastal Georgia and starting in September a total of 35 stations were selected each month; 25 stations in waters off Georgia, 10 stations off northeast Florida (Figure 2). Sampling effort and temporal coverage has reduced in recent years. The mainline for the GADNR SEAMAP survey is approximately 926 m in length consisting of 3.0 mm (273 kg) monofilament, containing 60 gangions. Gangions are 0.7 m of 1.6 mm (91 kg) monofilament terminating in either a 12/0 or 15/0 circle hook with the barb depressed. From 2007-2015, hook type was equally represented during a set. Beginning in 2016, only 15/0 circle hooks were used. In 2007 and 2016-2018, each set contained a combination of hooks baited with squid and hooks baited with fish. From 2008-2015, hooks were only baited with squid. For all years, soak times were 30 minutes in duration, measured from second anchor deployed to first anchor retrieved.

The station location, water and air temperatures, depth, salinity, and time of day were recorded for each set. 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 a NMFS blue rototag in the first dorsal fin or a steel tipped dart tag (M-tag) and released.

Data Analysis

Given the differences in bait (fish, squid) and hook (12/0, 15/0) types across years, sets allowing for a comparison using paired data were used to test for significant differences in blacktip shark catches. A non-parametric Wilcoxon signed-rank test ($p<0.5$) was used to test for differences in blacktip shark catches with respect to bait and hook type. For each factor, sets were chosen that had equal representation for both types of the tested factor while the other factor was held constant using only one type. Bait type was tested using sets from 2016-2018, where 30 of the 15/0 circle hooks were baited with fish and the other 30 were baited with squid. Hook type was tested using sets from 2008-2015, where 12/0 and 15/0 hooks were equally represented during each set and all hooks were baited with squid.

Catch per unit effort (CPUE) in number of sharks per 100 hook hours for the GADNR SEAMAP sets was used to examine the relative abundance blacktip sharks in Georgia's coastal waters. Exploratory sets and

sets conducted solely for specimen collection were excluded. Additionally, sets in northern Florida were excluded as these were not consistently sampled over time. Factors considered as potential influences on the GADNR SEAMAP sets were year (2007 – 2018), month (May-October) and strata (inshore, nearshore, offshore). Set bait (mixed, squid) and hook (mixed, 15/0) configuration could not be used as factors as there was no overlap within years. 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

Differences in blacktip shark catches for bait type (fish, squid) and hook type (12/0, 16/0) were significant for both factors (n= 80, Z= -3.6452, p= .00026 and n= 26, Z= -2.8446, p= .00452, respectively). Blacktip sharks were caught significantly more often on fish bait and smaller hooks than squid bait and larger hooks. A total of 229 blacktip sharks were caught during the 1666 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 Figure 2. The majority (92%) of the catch was under 100 cm fork length. Of the 217 measured fish, 51% were young of the year. The proportion of sets with positive catch (at least one blacktip shark caught) was 9.5%. Removal of young of the year reduces proportion positive to 5.6% and removal of age 1+ sharks reduces proportion positive to 4.6%. The stepwise construction of each model and the resulting statistics are detailed in Table 1. Model diagnostic plots reveal that the model fit is acceptable (Figures 3 and 4). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 2 and are plotted by year in Figure 5. The resulting relative abundance has an overall decreasing trend due to the high first year and is likely influenced by the change in bait and hook type. Highest estimate is in 2007, the only year where both mixed bait sets and mixed hook sets were used. Following this year there is a variable but overall increasing trend from 2008 to 2015 when the bait and hook type are held constant (squid bait, mixed hooks). There is another dip in 2016 when small hooks are removed but mixed baits are returned. The trend increases again for the remainder of the time series while the mixed baits and large hooks are held constant from 2016 to 2018. Running the analyses again without 2007 produces an overall increasing trend but retains the variability (Table 3, Figure 6).

Table 1. Results of the stepwise procedure for development of the GADNR SEAMAP 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.

PROPORTION POSITIVE-BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	455	473.4658	1.0406				
month	450	434.5120	0.9656	7.2074		38.95	<.0001
depth	453	438.4342	0.9678	6.9960		35.03	<.0001
stratum	453	442.6126	0.9771	6.1022		30.85	<.0001
temp	453	449.0315	0.9912	4.7473		24.43	<.0001
year	444	459.7471	1.0355	0.4901		13.72	0.2490
sal	452	471.6763	1.0435	-0.2787		1.79	0.6172
month +							
depth	448	392.3942	0.8759	15.8274	8.6200	42.12	<.0001
stratum	448	394.3968	0.8804	15.3950	8.1876	40.12	<.0001
temp	448	430.8350	0.9617	7.5822	0.3748	3.68	0.1591
year	439	422.6643	0.9628	7.4765	0.2691	11.85	0.3752
month + depth +							
stratum	446	375.0482	0.8409	19.1909	3.3634	17.35	0.0002
year	437	377.0612	0.8628	17.0863	1.2589	15.33	0.1678
month + depth + stratum +							
year	435	361.4099	0.8308	20.1614	0.9706	13.6400	0.2537

FINAL MODEL: month + depth + stratum + year

AIC 1401.7 **BIC** 1405.3 **(-2) Res LL** 1399.7

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	month	depth	stratum	year
DF	5	1	2	11
CHI SQUARE	28.20	12.82	11.37	8.05

POSITIVE CATCHES-POISSON ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	103	47.2502	0.4587				
month	98	41.6340	0.4248	7.3905		13.16	0.0219
depth	102	44.7039	0.4383	4.4474		5.76	0.0164
temp	102	45.0823	0.4420	3.6407		4.88	0.0271
year	92	40.9827	0.4455	2.8777		14.80	0.1918
stratum	101	45.9627	0.4551	0.7848		2.87	0.2377
sal	100	46.6953	0.4670	-1.8095		1.23	0.7462
month +							
year	87	35.5529	0.4087	10.9004	7.2596	16.42	0.1262
temp	97	40.4696	0.4172	9.0473	4.6000	2.95	0.0859
depth	97	40.4086	0.4166	9.1781	1.7877	3.11	0.0779

FINAL MODEL: month + year

AIC 208.4 **BIC** 210.9 **(-2) Res LL** 206.4

Type 3 Test of Fixed Effects

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	month	year
DF	5	11
CHI SQUARE	13.43	15.14

Table 2. GADNR SEAMAP 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 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
2007	42	14	0.3333	3.9696	4.5718	2.1948	9.5229	0.3796
2008	42	11	0.2619	1.5873	1.8697	0.7967	4.3876	0.4467
2009	21	3	0.1429	0.4762	0.7951	0.1677	3.7702	0.9123
2010	39	5	0.1282	0.8547	0.7849	0.2165	2.8463	0.7171
2011	34	5	0.1471	1.9608	1.8460	0.5421	6.2862	0.6749
2012	41	9	0.2195	1.4634	1.4073	0.5362	3.6934	0.5119
2013	48	7	0.1458	0.5556	0.7885	0.2628	2.3660	0.5936
2014	58	11	0.1897	1.2644	1.9057	0.8122	4.4713	0.4466
2015	40	11	0.2750	1.9167	2.3139	1.0094	5.3046	0.4333
2016	44	9	0.2045	0.8333	1.4027	0.5564	3.5361	0.4881
2017	37	8	0.2162	1.6216	2.1665	0.8113	5.7855	0.5223
2018	37	12	0.3243	2.2727	2.3097	1.0040	5.3136	0.4353

Table 3. GADNR SEAMAP survey blacktip shark analysis, without the year 2007, 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 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
2008	42	11	0.2619	1.5873	1.9962	0.9228	4.3180	0.4006
2009	21	3	0.1429	0.4762	0.8296	0.1941	3.5458	0.8335
2010	39	5	0.1282	0.8547	0.7799	0.2344	2.5947	0.6596
2011	34	5	0.1471	1.9608	1.9484	0.6297	6.0290	0.6130
2012	41	9	0.2195	1.4634	1.4127	0.5830	3.4227	0.4651
2013	48	7	0.1458	0.5556	0.7679	0.2776	2.1239	0.5435
2014	58	11	0.1897	1.2644	2.0178	0.9306	4.3751	0.4019
2015	40	11	0.2750	1.9167	2.4305	1.1522	5.1271	0.3866
2016	44	9	0.2045	0.8333	1.4213	0.6134	3.2932	0.4394
2017	37	8	0.2162	1.6216	2.1472	0.8759	5.2641	0.4719
2018	37	12	0.3243	2.2727	2.3650	1.1075	5.0502	0.3934

Figure 1. GADNR SEAMAP sampling areas retained for index development included the SGA region with three strata. Strata included the Georgia inshore waters within the sound systems, nearshore waters outside the sound systems but within state waters, and offshore artificial reefs in federal waters.

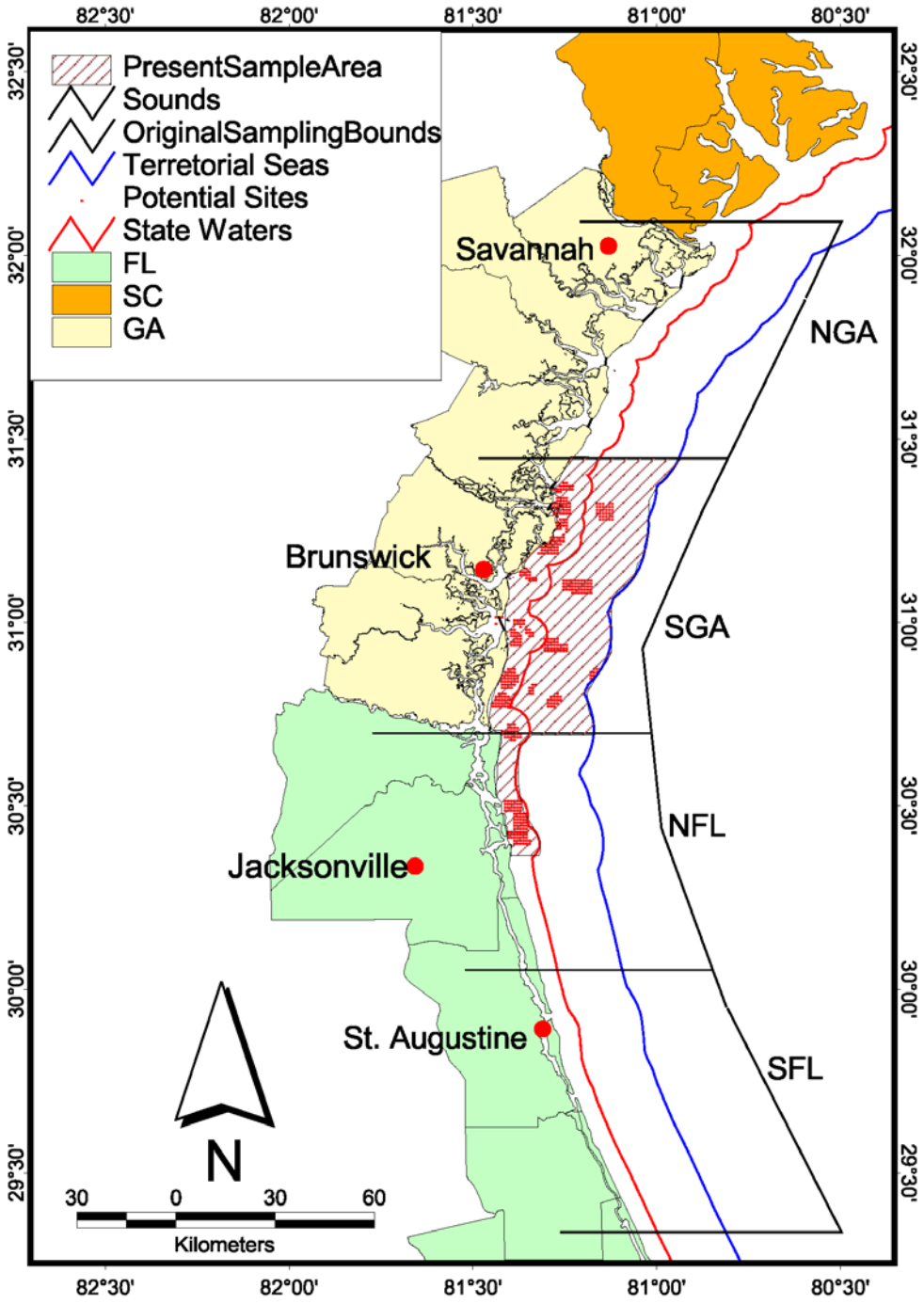


Figure 2. Fork lengths (cm) of blacktip sharks caught during the GADNR SEAMAP longline survey from 2007-2018.

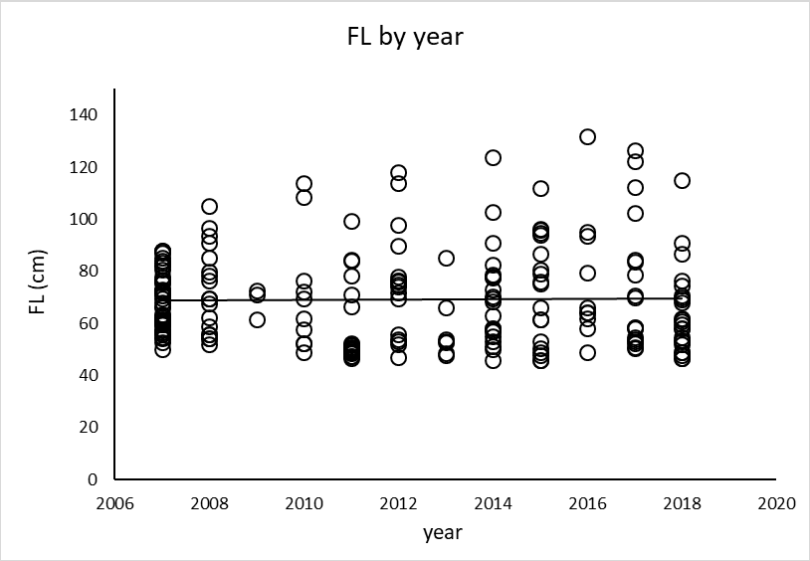


Figure 3. Model diagnostic plots for the binomial component.

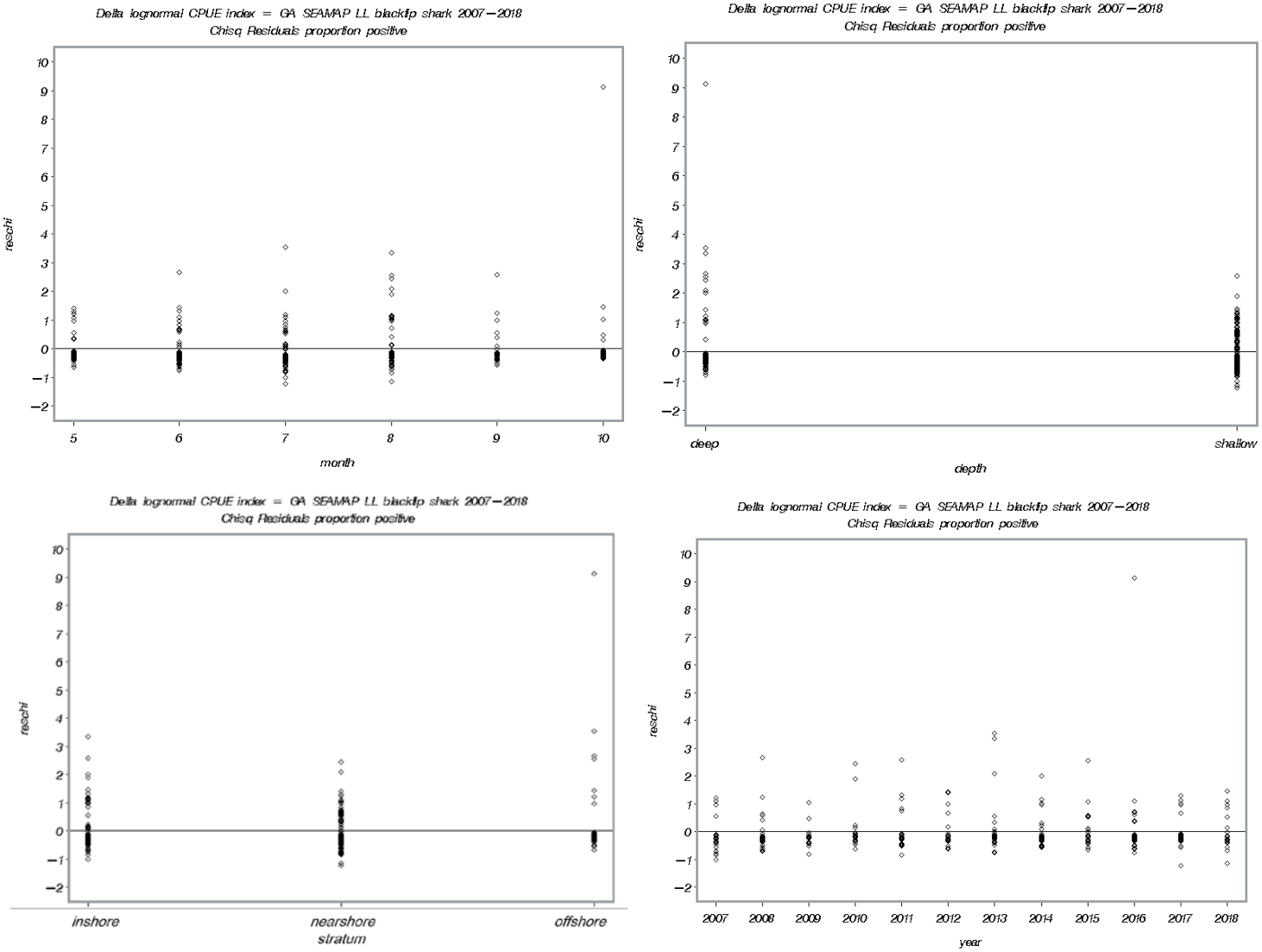
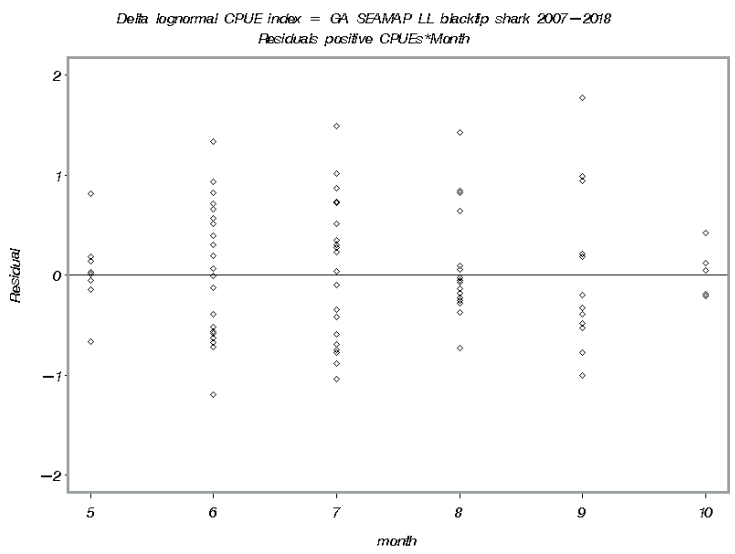
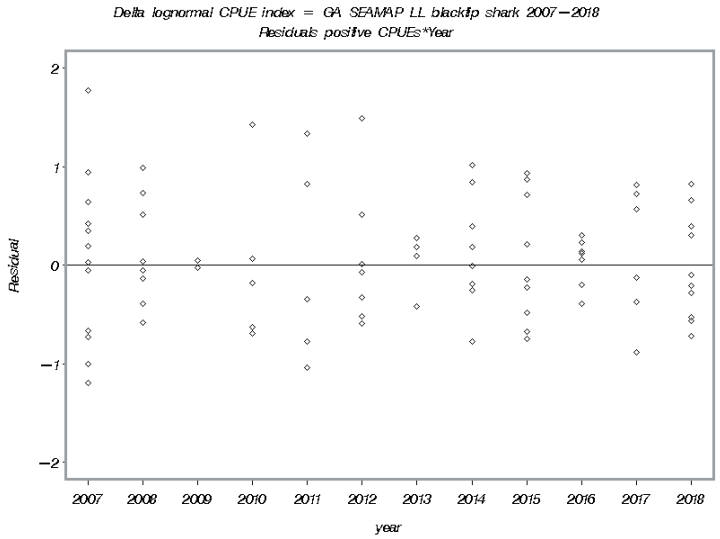
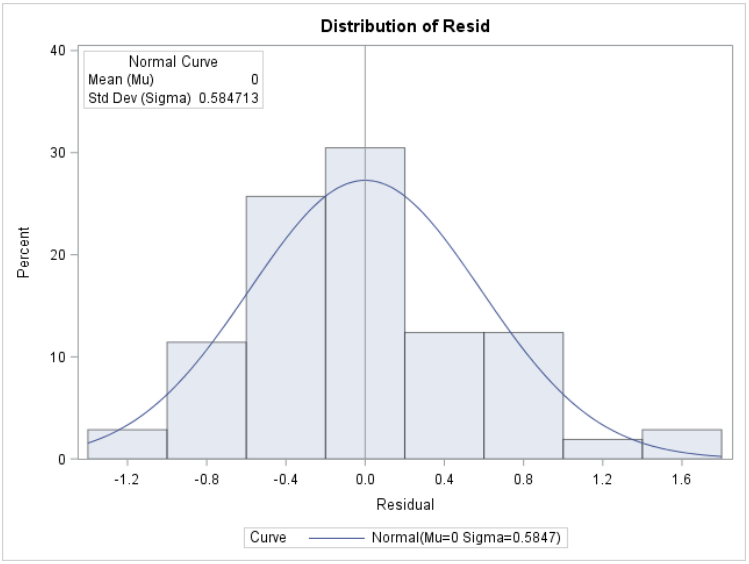


Figure 4. Model diagnostic plots for the lognormal component.







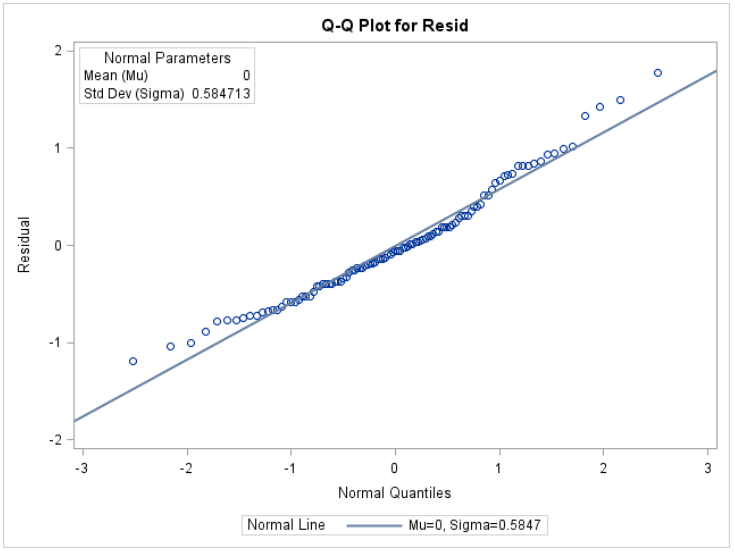


Figure 5. GADNR SEAMAP survey blacktip shark nominal (obscpue) and estimated (estcpue) indices with 95% confidence limits (LCI0, UCI0).

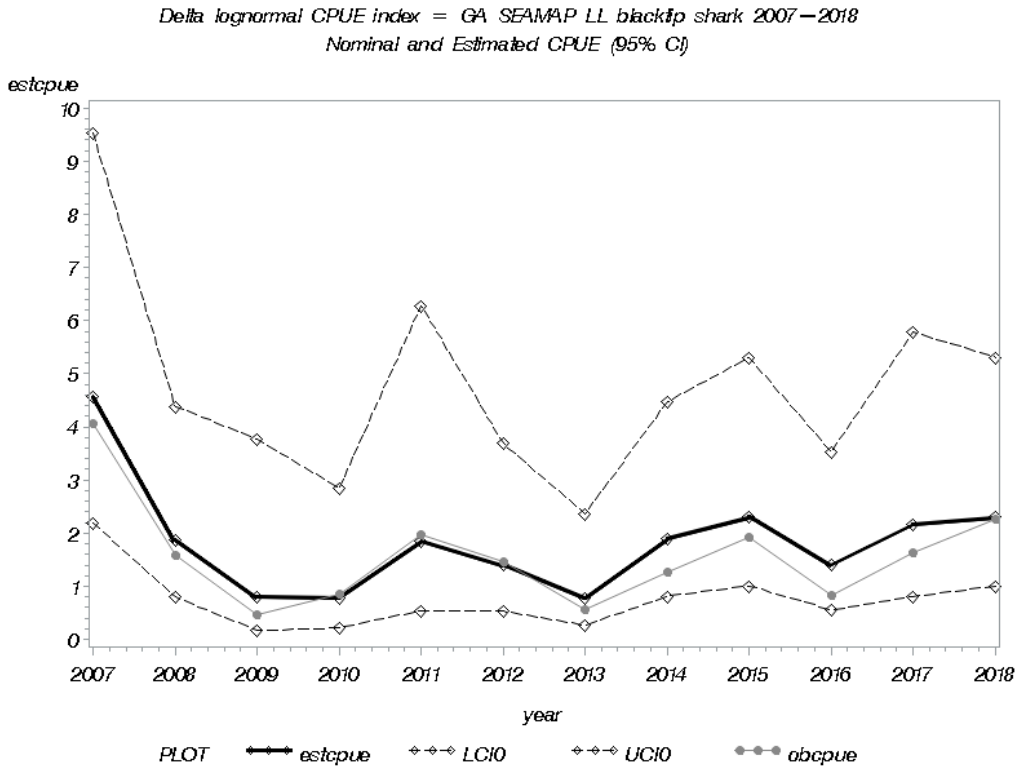


Figure 6. GADNR SEAMAP survey, excluding the year 2007, blacktip shark nominal (obscpue) and estimated (estcpue) indices with 95% confidence limits (LCI0, UCI0).