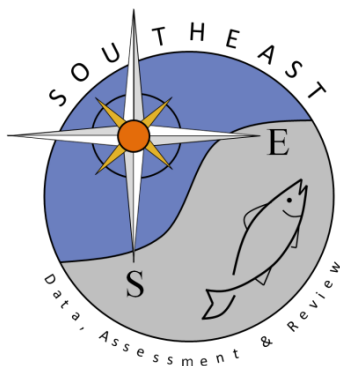


Standardized index of abundance for sandbar sharks from the
NOAA Cooperative Atlantic States Shark Pupping and Nursery
longline survey conducted in South Carolina, Georgia, and
northern Florida

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SEDAR 101 DATA WORKSHOP DOCUMENT**Standardized index of abundance for sandbar sharks from the NOAA Cooperative Atlantic States Shark Pupping and Nursery longline survey conducted in South Carolina, Georgia, and northern Florida**

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Workshop Draft not to be cited without permission of authors

Summary

This document details the sandbar 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 juvenile sandbar shark relative abundance from 2000-2024. 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. This time series shows high uncertainty at the beginning of the time series, when it was as much exploration as survey. The resulting indices show a lot of variability across years that might be expected for a recruitment index, especially for a fish with a reproductive cycle of two to three years.

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. In 2016 UNF took over the sampling in Georgia waters when GADNR was no longer able to conduct the survey. 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 sandbar sharks <80 cm fork length to produce a recruitment index. 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 analysis, factors considered as potential influences on the catch were year (2001-2019), 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 Sound, St. Simons Sound, St. Andrew Sound, Cumberland Sound, and Nassau Sound). 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 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 1304 sandbar sharks (<80 cm FL), including 927 young-of-the-year, were caught during the 1652 longline sets conducted during the summer months from 2000 to 2024. Two indices were developed using this data, one for sandbar sharks <80 cm FL and after review and discussions with the Indices Working Group, another for age 0 sharks (<63.6 cm FL). The size of sandbar sharks caught by this gear ranges from newborn pups up to the occasional adult female. The majority (88%) of the catch is under 80 cm fork length, which were plotted by year in Figure 1 using multiple methods. The proportion of sets with positive catch with least one shark <80cm fork length caught was 31%, and the proportion positive for YOY was 26%. Histograms of annual set catch data show a persistent zero-inflated distribution, appropriate for standardization with the delta-lognormal model (Figure 2). The stepwise construction of each model and the resulting statistics are detailed in Tables 1 and 2. Model diagnostic plots reveal that the model fit is acceptable for juvenile sandbar sharks (Figures 3, 4, 7, and 8). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal index are reported in Tables 3 and 4 are plotted by year in Figures 5 and 7. A plot of the indices re-modeled after removing the last year, 5 consecutive times, is located in Figures 6 and 8 for retrospective analysis.

Table 1. Results of the stepwise procedure for development of a recruitment index using the SE COASTSPAN catch rate of sandbar sharks <80 cm fork length. %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							POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION								
FACTOR	DF	DEVIANCE	DEVIANCE%DIFF	DELTA%	CHISQ	PR>CHI	FACTOR	DF	DEVIANCE	DEVIANCE%DIFF	DELTA%	CHISQ	PR>CHI		
null	1858	2396.8773	1.29				null	653	375.5858	0.5752					
area	1853	2021.0017	1.0907	15.450	375.88	<.0001	year	630	339.963	0.5396	6.189	65.17	<.0001		
year	1830	1907.0755	1.0421	19.217	113.93	<.0001	area	648	350.5486	0.541	5.946	45.12	<.0001		
sal	1854	2291.1462	1.2358	4.202	105.73	<.0001	set	644	353.3912	0.5487	4.607	39.84	<.0001		
depth	1857	2317.6608	1.2481	3.248	79.22	<.0001	sal	649	365.8261	0.5637	1.999	17.22	0.0018		
set	1849	2370.6164	1.2821	0.612	26.26	0.0019	temp	652	374.1124	0.5738	0.243	2.57	0.1089		
temp	1857	2395.1791	1.2898	0.016	1.7	0.1925	month	651	373.8014	0.5742	0.174	3.11	0.2107		
month	1856	2396.5587	1.2912	-0.093	0.32	0.8528	depth	652	374.5232	0.5744	0.139	1.85	0.1735		
AREA +							YEAR +								
year	1823	1903.0938	1.0439	19.078	3.6279	93.03	<.0001	set	621	313.3559	0.5046	12.274	6.085	53.30	<.0001
sal	1849	1962.5269	1.0614	17.721	2.2713	58.47	<.0001	area	625	316.0255	0.5066	11.926	5.737	47.75	<.0001
depth	1852	2005.9348	1.0831	16.039	0.5891	15.07	0.0001	sal	626	328.3291	0.5245	8.814	2.625	22.77	0.0001
AREA + YEAR +							YEAR + SET +								
sal	1826	1863.8052	1.0207	20.876	1.7984	43.27	<.0001	area	616	290.4263	0.4715	18.029	6.102	49.7	<.0001
AREA + YEAR + SAL +							YEAR + SET + AREA +								
year*area	1747	1707.3021	0.9773	24.240	6.212	negative hessian	year*area	550	229.8882	0.418	27.330	9.301	152.88	<.0001	
year*sal	1774	1758.0451	0.9910	23.178	5.150	negative hessian	area*set	585	275.9081	0.4716	18.011	-0.017	33.54	0.3452	
area*sal	1807	1796.8599	0.9944	22.915	2.039	negative hessian	year*set	504	244.1621	0.4844	15.786	-2.243	113.48	0.4431	
FINAL MODEL: AREA + YEAR + SAL							FINAL MODEL: YEAR + SET+ AREA + YEAR*AREA								
Type 3 Test of Fixed Effects Results for the Final Model using SAS MIXED procedure							Type 3 Test of Fixed Effects Results for the Final Model using SAS MIXED procedure								
Significance (Pr>Chi) of Type 3			year	area	sal		Significance (Pr>Chi) of Type 3			year	set	area	year*area		
test of fixed effects for each factor			<.0001	<.0001	<.0001		test of fixed effects for each factor			0.0054	<.0001	<.0001	<.0001		
DF			23	5	4		DF			23	9	5	67		
CHI SQUARE			63.18	166.01	27.67		CHI SQUARE			43.90	56.84	34.58	148.76		

Table 2. Results of the stepwise procedure for development of a recruitment index using the SE COASTSPAN catch rate of **YOY sandbar sharks** (<63.6 cm fork length. %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%DIFF	DELTA%	CHISQ	PR>CHI
null	1858	2138.6466	1.1510			
area	1853	1778.4680	0.9598	16.612	360.18	<.0001
year	1830	1907.0755	1.0421	9.461	148.64	<.0001
depth	1857	2057.1854	1.1078	3.753	81.46	<.0001
sal	1854	2057.4906	1.1098	3.579	81.16	<.0001
set	1849	2110.1863	1.1413	0.843	28.46	0.0008
temp	1857	2131.5198	1.1478	0.278	7.13	0.0076
month	1856	2136.6913	1.1512	-0.017	1.96	0.3762
AREA +						
sal	1826	1625.2007	0.8900	22.676	6.0643	<.0001
depth	1829	1650.9103	0.9026	21.581	4.9696	0.0003
year	1830	1663.7453	0.9092	21.008	4.3962	<.0001
AREA + SAL +						
year	1826	1625.2007	0.8900	22.676	0.0000	<.0001
depth	1848	1705.9176	0.9231	19.800	-1.7811	<.0001
AREA + SAL + YEAR						
area*sal	1807	1586.8808	0.8782	23.701	1.025	negative hessian

FINAL MODEL: AREA + SAL + YEAR

Type 3 Test of Fixed Effects Results for the Final Model using SAS MIXED procedure

Significance (Pr>Chi) of Type 3	year	area	sal
test of fixed effects for each factor	<.0001	<.0001	<.0001
DF	23	5	4
CHI SQUARE	64.96	162.94	26.93

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE%DIFF	DELTA%	CHISQ	PR>CHI
null	504	255.8433	0.5076			
year	482	228.7598	0.4746	6.501	56.51	<.0001
set	495	236.1748	0.4771	6.009	40.40	<.0001
area	499	238.437	0.4778	5.871	35.58	<.0001
sal	500	252.4878	0.5050	0.512	6.67	0.1546
temp	503	255.8393	0.5086	-0.197	0.01	0.9289
month	502	253.4411	0.5049	0.532	4.76	0.0924
depth	503	255.841	0.5086	-0.197	0	0.9463
YEAR +						
set	473	206.909	0.4374	13.830	7.329	<.0001
area	477	214.6596	0.4500	11.348	4.846	<.0001
YEAR + SET +						
area	468	194.9637	0.4166	17.928	6.580	<.0001
YEAR + SET + AREA +						
year*area	411	154.9794	0.3771	25.709	7.782	<.0001
area*set	440	179.7788	0.4086	19.504	1.576	0.0543
year *set	370	158.9356	0.4296	15.366	-2.561	103.18

FINAL MODEL: YEAR + SET+ AREA + YEAR*AREA

Type 3 Test of Fixed Effects Results for the Final Model using SAS MIXED procedure

Significance (Pr>Chi) of Type 3	year	set	area	year*area
test of fixed effects for each factor	0.3503	0.0016	0.0015	0.0002
DF	22	1	5	58
CHI SQUARE	23.94	9.92	19.62	105.08

Table 3. SE COASTSPAN LL index results for **sandbar sharks (< 80 cm FL)** 2000-2024. Table columns: number of sets per year (n obs), number of positive sets per year (obs pos), proportion of positive sets per year (obs ppos), nominal cpue as sharks per hook (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
2000	57	3	0.0526	0.2275	0.1935	0.0447	0.8380	0.8433
2001	23	6	0.2609	2.5837	4.5485	1.0959	18.8792	0.8120
2002	2	0	0.0000	0.0000				
2003	55	12	0.2182	2.6531	1.3069	0.4074	4.1930	0.6361
2004	65	22	0.3385	5.8147	2.1321	0.6977	6.5150	0.6050
2005	89	29	0.3258	4.5420	1.1083	0.4300	2.8569	0.5013
2006	78	22	0.2821	3.8225	2.4258	0.9931	5.9252	0.4697
2007	60	25	0.4167	4.2777	2.6822	1.0995	6.5430	0.4690
2008	71	20	0.2817	2.1913	2.7641	1.5370	4.9709	0.2999
2009	130	24	0.1846	1.3188	1.9267	1.1063	3.3553	0.2828
2010	149	33	0.2215	2.3086	3.0677	1.8876	4.9857	0.2464
2011	158	48	0.3038	2.4039	3.5145	2.5153	4.9107	0.1684
2012	149	48	0.3221	2.1459	2.5519	1.7664	3.6869	0.1855
2013	155	52	0.3355	2.6310	3.4100	1.9649	5.9178	0.2810
2014	86	18	0.2093	2.3557	2.5427	1.3728	4.7096	0.3156
2015	118	29	0.2458	1.3287	1.8130	1.1296	2.9098	0.2399
2016	143	33	0.2308	1.6392	1.6880	0.9616	2.9632	0.2870
2017	114	47	0.4087	3.5915	3.0910	2.0444	4.6734	0.2089
2018	147	60	0.4082	2.8048	2.9931	2.1655	4.1370	0.1629
2019	90	49	0.5444	8.0902	7.1769	5.2410	9.8278	0.1582
2020	98	63	0.6429	5.6475	5.8669	4.1306	8.3330	0.1768
2021	99	46	0.4646	6.1703	6.1226	3.8507	9.7350	0.2350
2022	104	19	0.1827	0.9097	1.0125	0.5338	1.9207	0.3285
2023	94	27	0.2872	1.6805	1.6873	0.8647	3.2926	0.3438
2024	51	19	0.3725	2.5132	1.8240	0.8338	3.9899	0.4068

Table 4. SE COASTSPAN LL index results for **YOY sandbar sharks** (< 63.6 cm FL) 2000-2024. Table columns: number of sets per year (n obs), number of positive sets per year (obs pos), proportion of positive sets per year (obs ppos), nominal cpue as sharks per hook (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	obcpue	estcpue	LCL	UCL	CV
2000	57	2	0.0351	0.1924	0.1755	0.0269	1.1442	1.1868
2001	23	1	0.0435	0.8027				
2002	2	0	0.0000	0.0000				
2003	55	12	0.2182	2.4350	1.3293	0.3418	5.1694	0.7654
2004	65	17	0.2615	3.4521	1.7618	0.4643	6.6852	0.7482
2005	89	27	0.3034	3.9245	1.0135	0.3154	3.2572	0.6372
2006	78	19	0.2436	2.9100	1.9815	0.6237	6.2951	0.6298
2007	60	22	0.3667	3.6727	2.8475	0.8773	9.2426	0.6436
2008	71	15	0.2113	1.7406	2.4526	1.1453	5.2523	0.3950
2009	130	15	0.1154	0.4850	1.1298	0.4890	2.6105	0.4378
2010	149	30	0.2013	1.8843	2.5829	1.4848	4.4930	0.2822
2011	158	39	0.2468	1.4477	2.8705	1.8644	4.4196	0.2183
2012	149	41	0.2752	1.7312	2.3513	1.5026	3.6792	0.2267
2013	155	42	0.2710	2.0501	3.0303	1.5489	5.9286	0.3452
2014	86	16	0.1860	2.0519	2.2455	1.0711	4.7079	0.3832
2015	118	4	0.0339	0.2034	0.2198	0.0463	1.0443	0.9139
2016	143	29	0.2028	1.3478	1.4753	0.7224	3.0129	0.3687
2017	114	33	0.2870	2.8898	2.6702	1.3565	5.2562	0.3486
2018	147	46	0.3129	1.4976	1.9252	1.2546	2.9541	0.2166
2019	90	38	0.4222	4.6392	5.5128	3.4513	8.8058	0.2374
2020	98	49	0.5000	3.7379	3.6272	2.2886	5.7487	0.2333
2021	99	38	0.3838	3.6918	3.5529	1.8828	6.7043	0.3257
2022	104	14	0.1346	0.6530	0.8633	0.3850	1.9356	0.4207
2023	94	22	0.2340	1.2572	1.2192	0.5213	2.8518	0.4448
2024	51	14	0.2745	1.4163	1.2715	0.4702	3.4383	0.5298

Figure 1. Fork lengths (cm) of juvenile sandbar sharks (<80 cm fork length) caught during the SE COASTSPAN longline surveys in South Carolina, Georgia, and northern Florida from 2000-2024 plotted multiple ways. First two plots by year and the third one by sex and year.

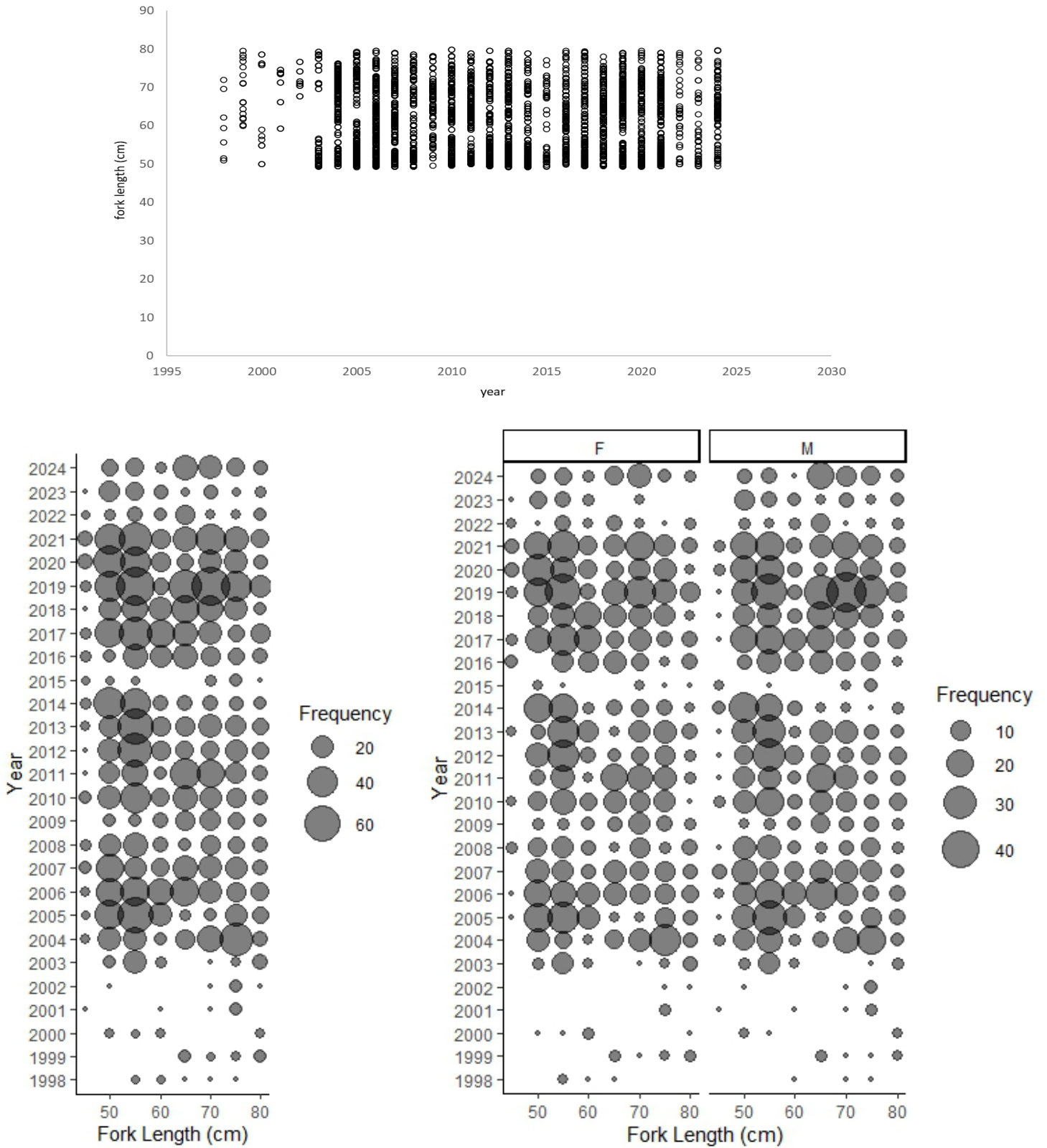


Figure 2. Histograms of set catch data by year showing the zero-inflated distribution over time

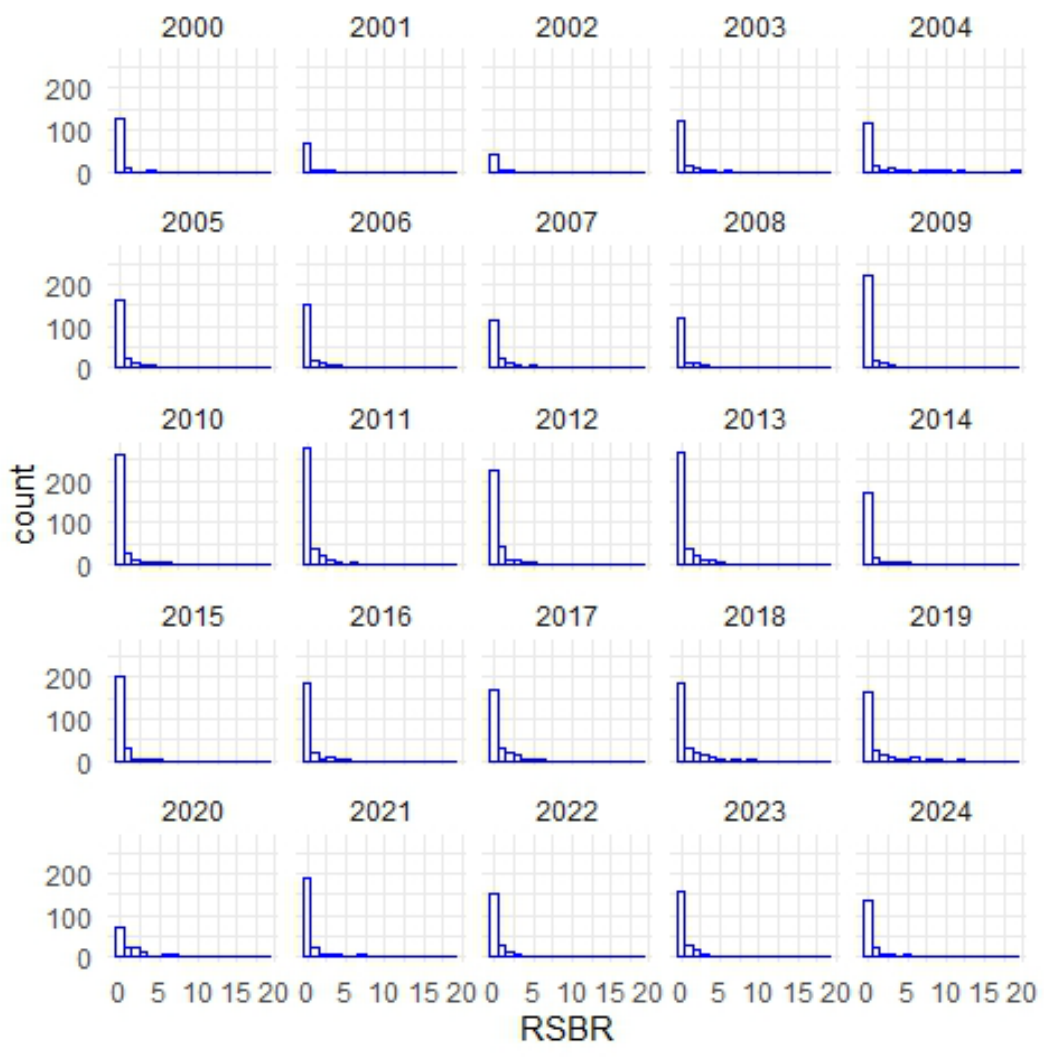


Figure 3. Diagnostic plots for the **binomial component** of the SE COASTSPAN LL catch rate model for **sandbar sharks (<80 cm FL)**.

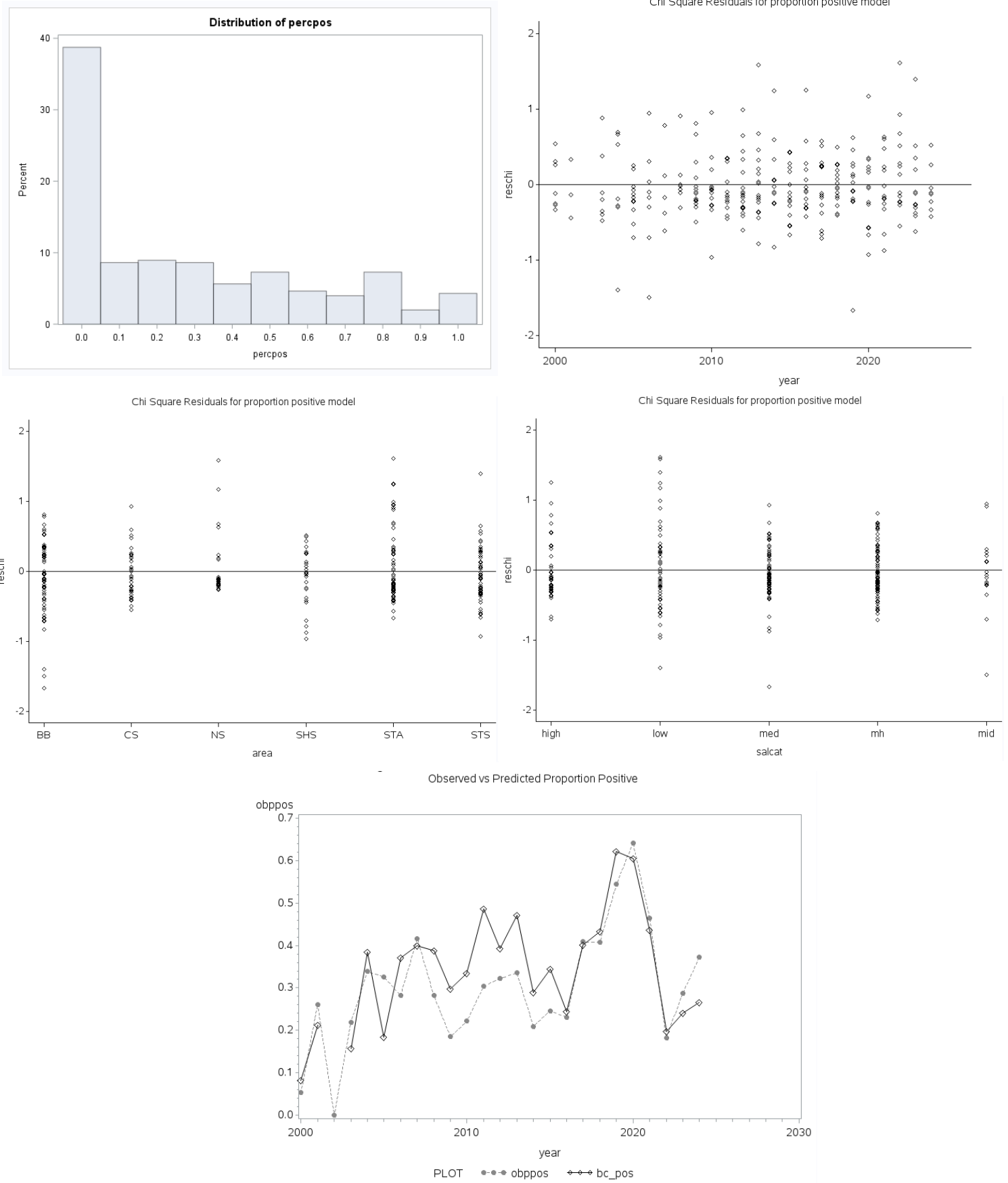


Figure 4. Diagnostic plots for the **lognormal component** of the SEAMAP LL ATL catch rate model for **sandbar sharks (<80 cm FL)**.

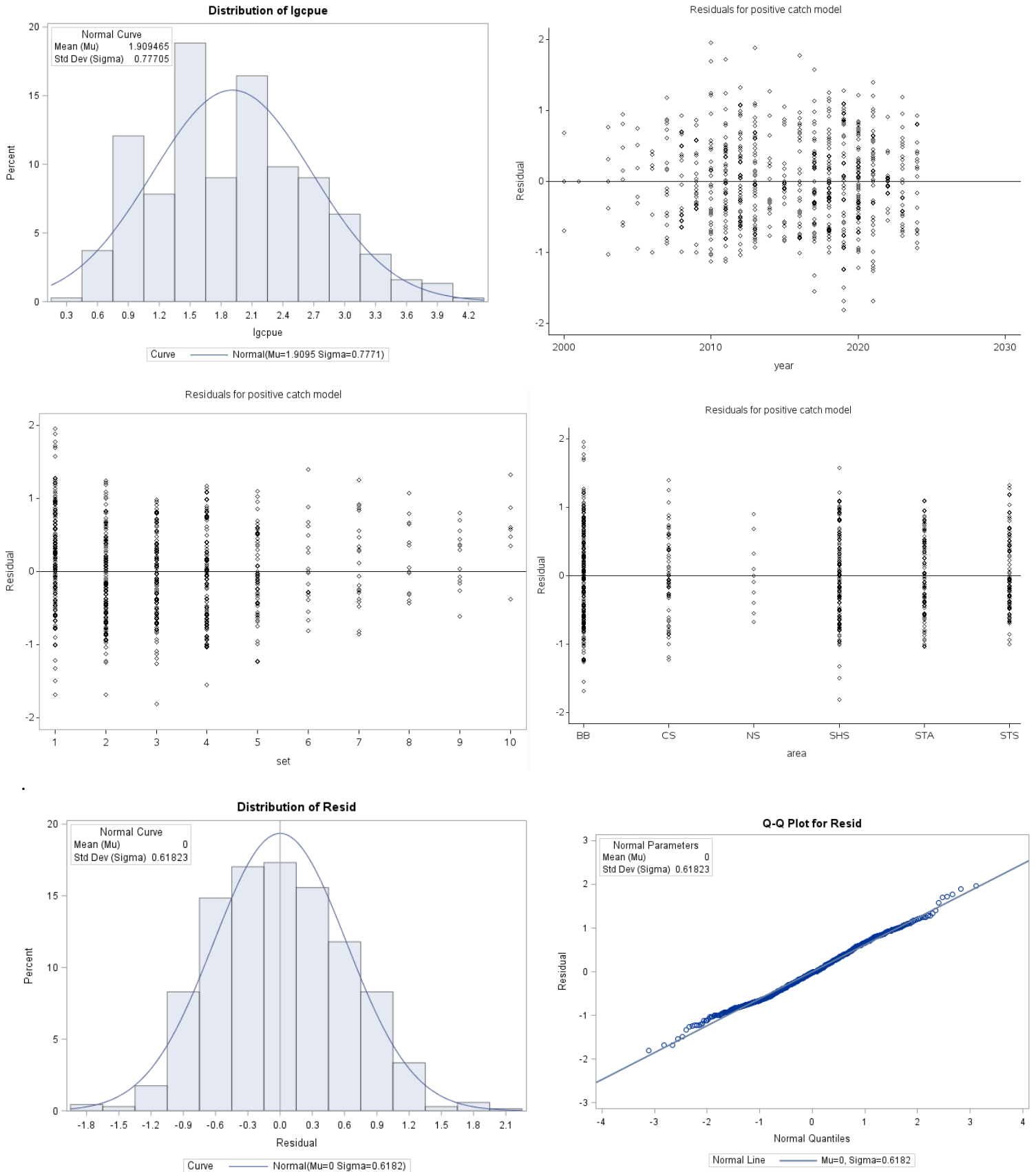


Figure 5. SE COASTSPAN index for **sandbar shark (<80 cm FL)** relative abundance (estcpue) with 95% confidence intervals (LCI0, UCI0) and overlaid with the nominal catch-per-unit-effort data. (obcpue)

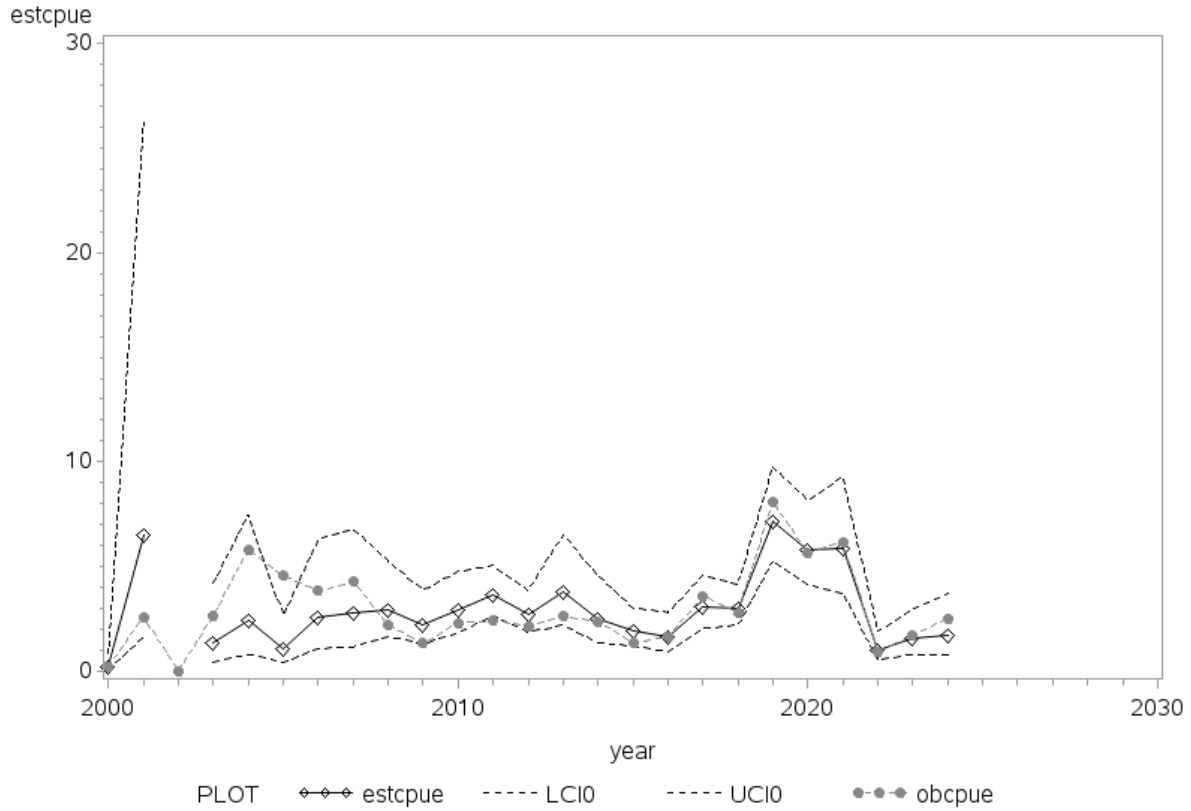


Figure 6. Retrospective analysis for sandbar sharks (<80 cm fork length)

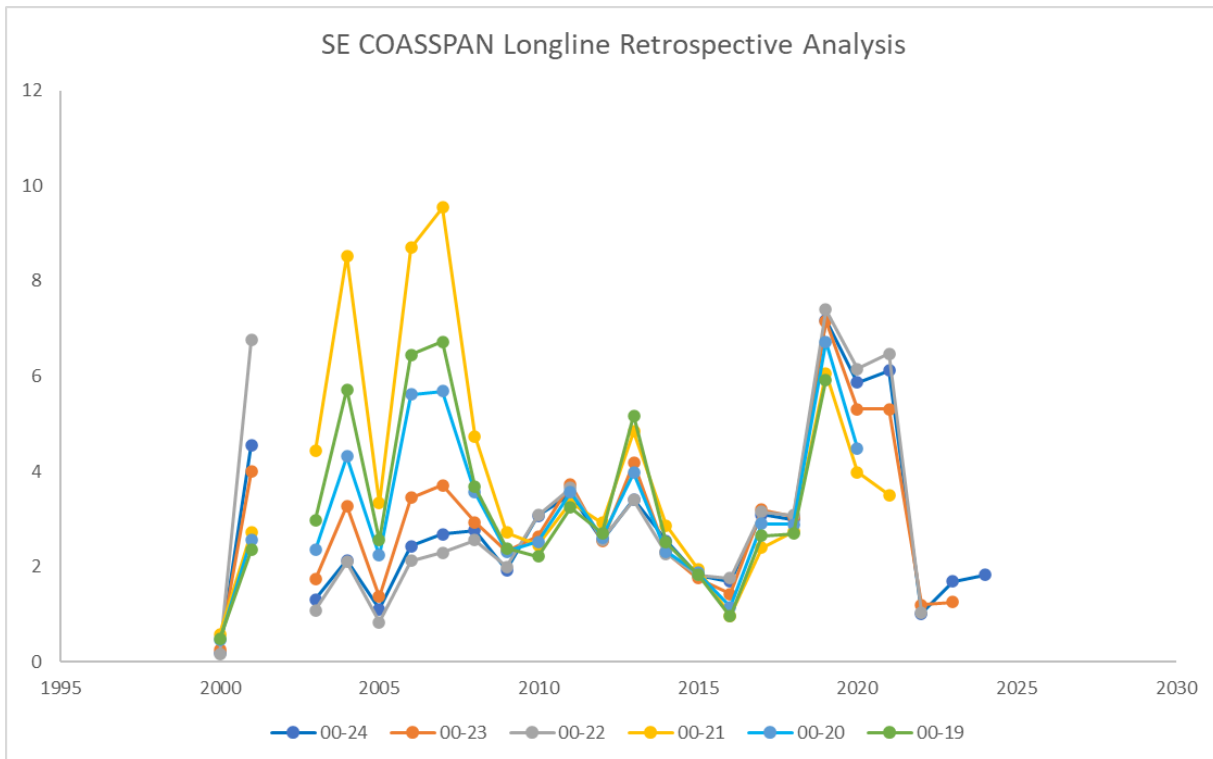


Figure 7. Diagnostic plots for the **binomial component** of the SE COASTSPAN LL catch rate model for YOY sandbar sharks (<63.6 cm FL).

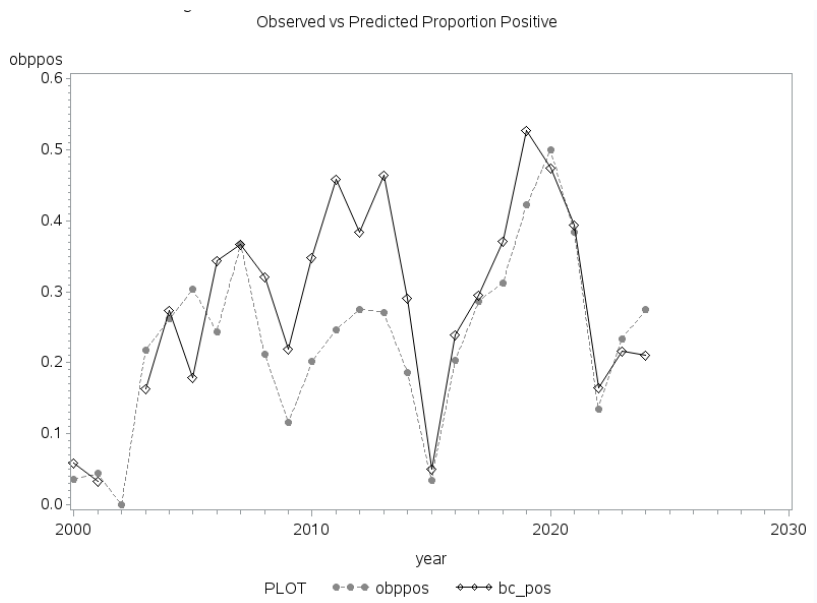
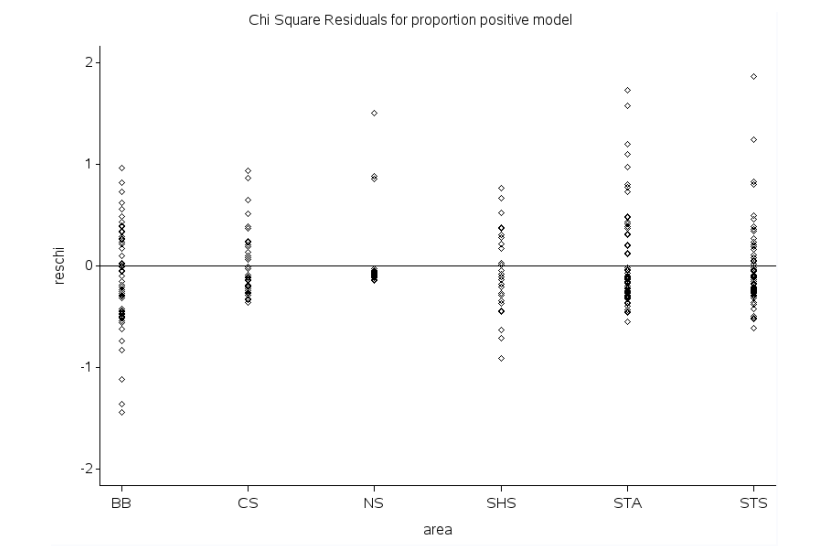
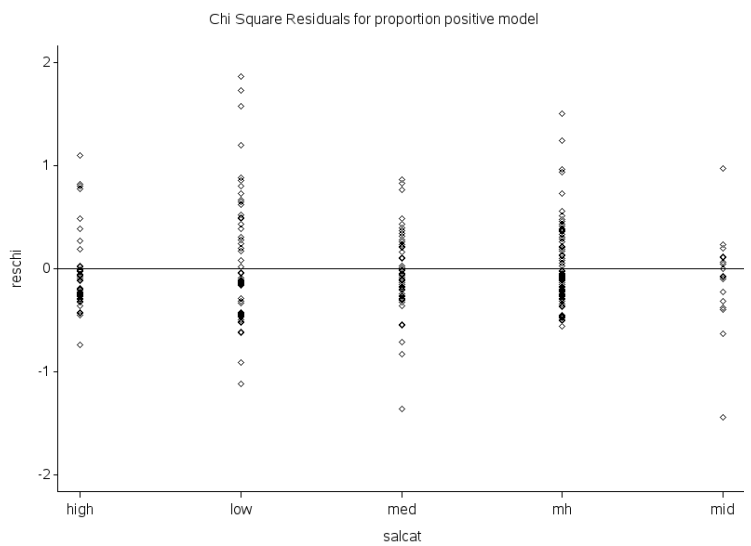
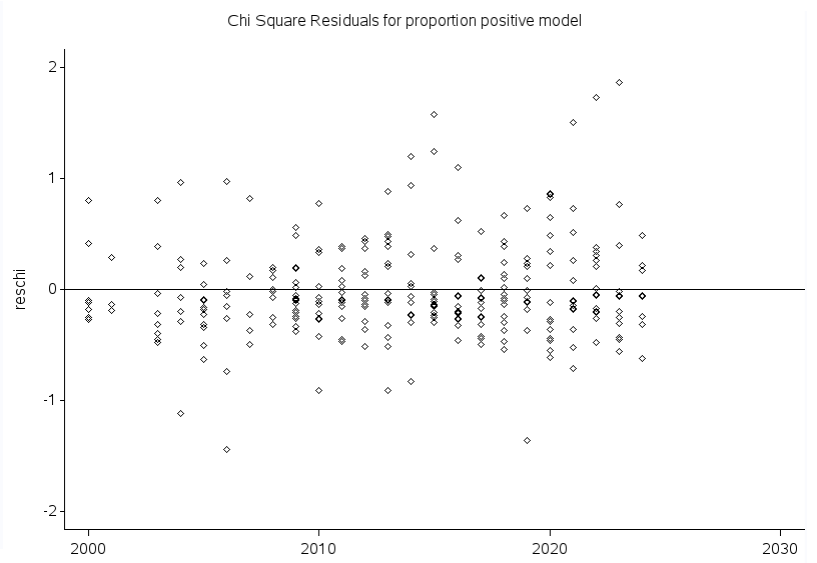
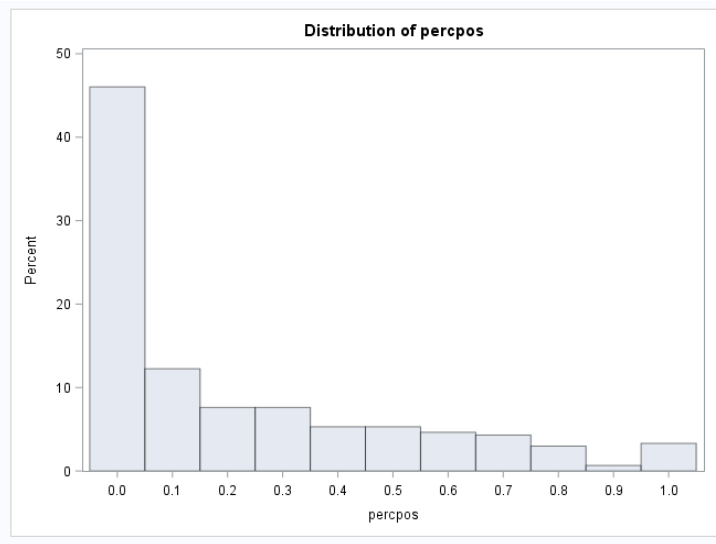


Figure 7. Diagnostic plots for the **lognormal component** of the SEAMAP LL ATL catch rate model for **YOY sandbar sharks (<63.6 cm FL)**.

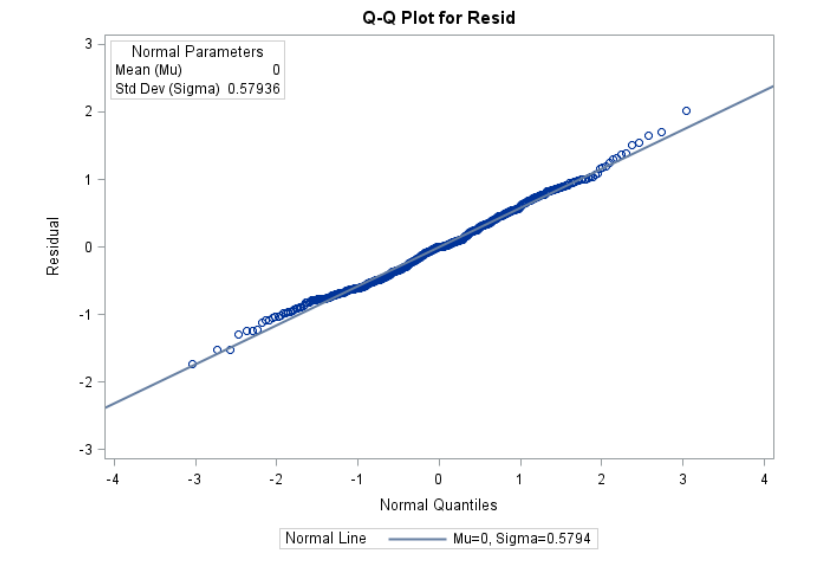
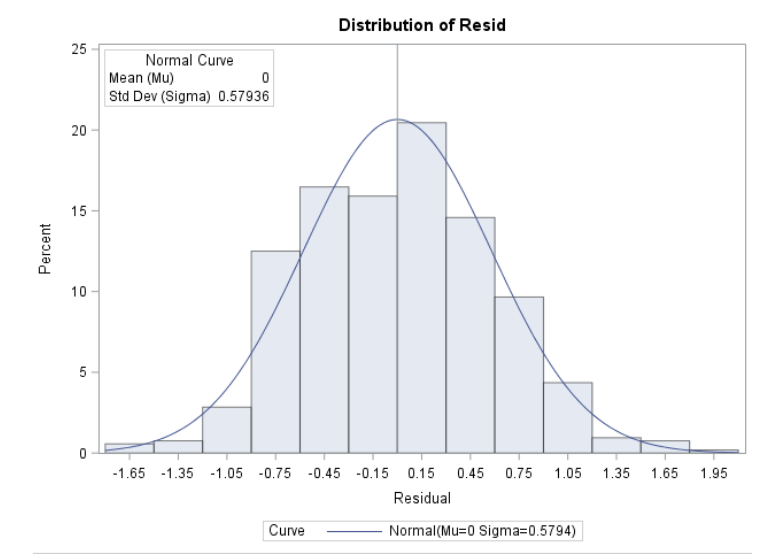
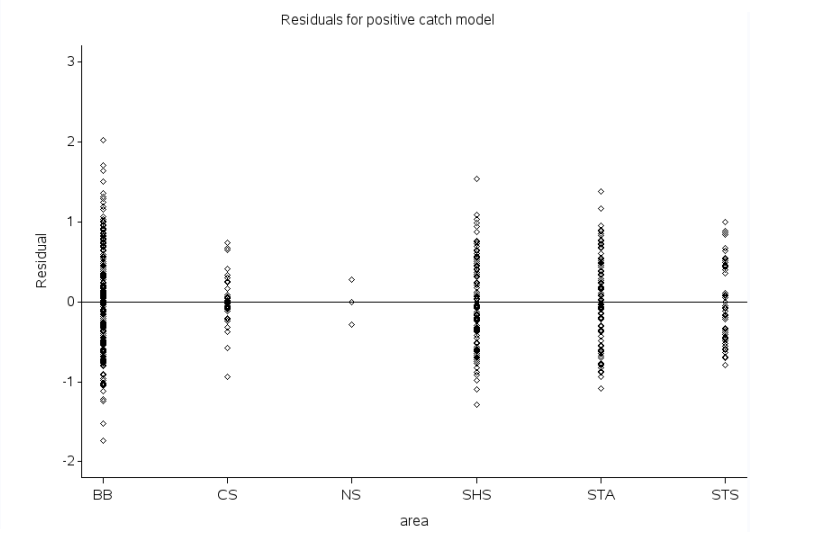
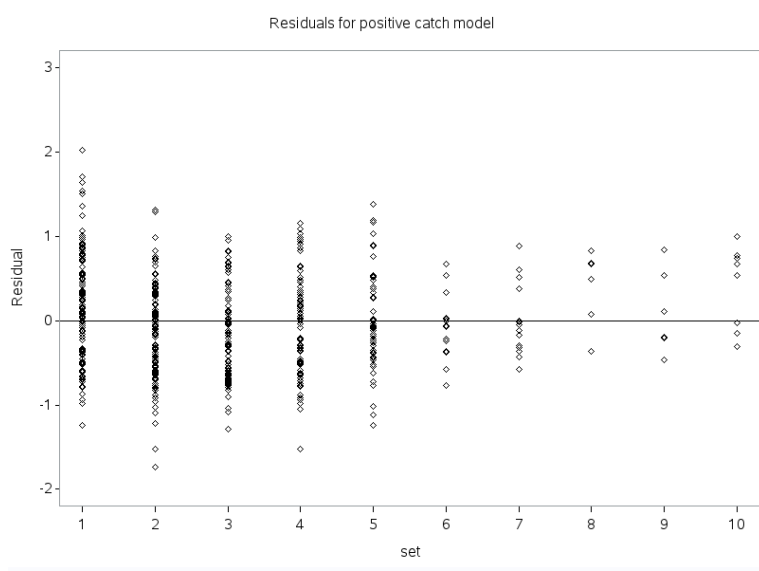
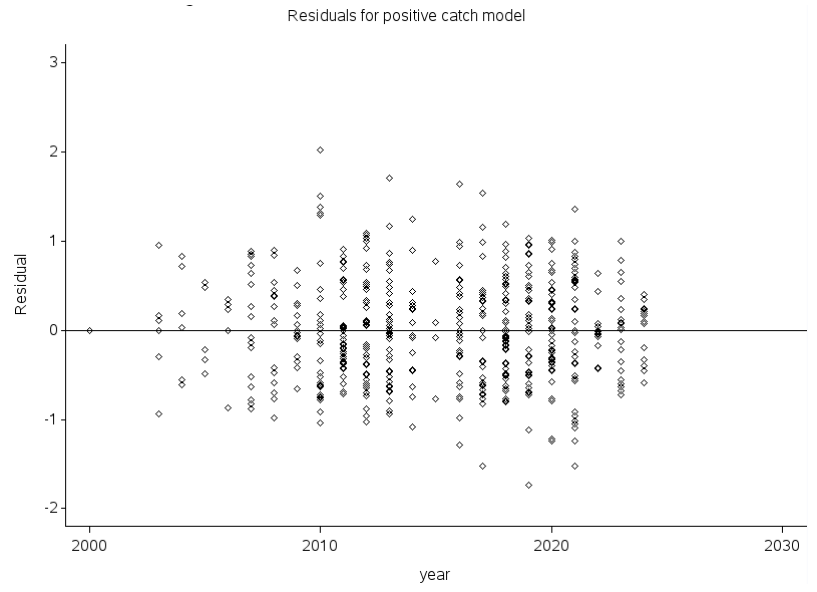
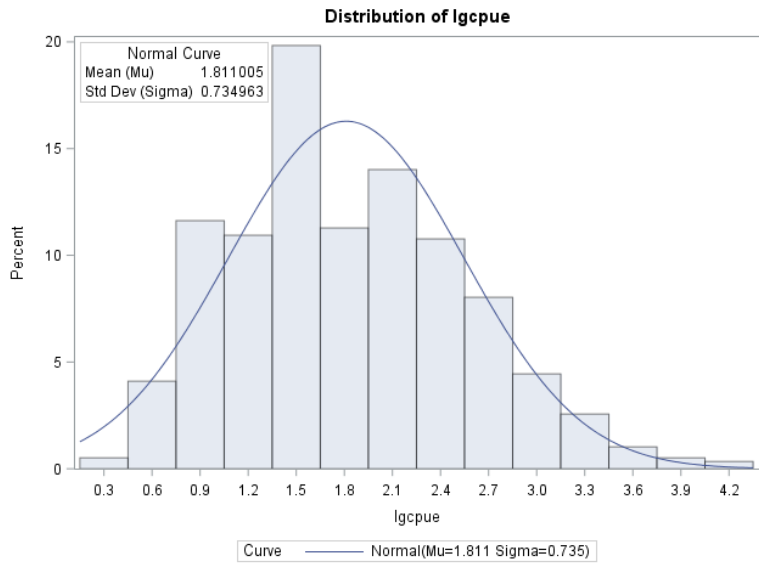


Figure 8. SE COASTSPAN index for **YOY sandbar shark (<63.6 cm FL)** relative abundance (estcpue) with 95% confidence intervals (LCI0, UCI0) and overlaid with the nominal catch-per-unit-effort data. (obcpue)

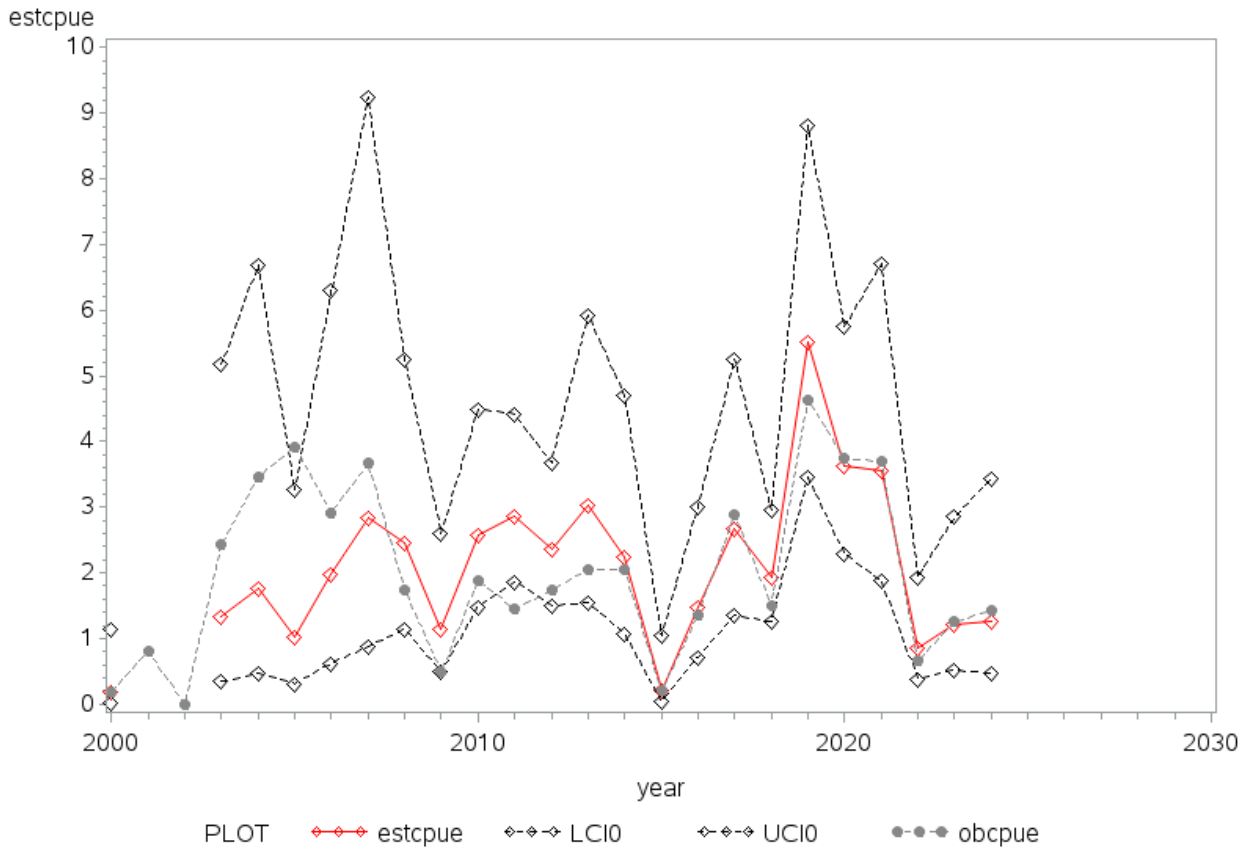


Figure 9. Retrospective analysis for YOY sandbar shark index

