Standardized catch rates for juvenile sandbar sharks caught during northeast COASTSPAN longline surveys

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SEDAR 101 DRAFT DATA WORKSHOP DOCUMENT

Standardized catch rates for juvenile sandbar sharks caught during northeast COASTSPAN longline surveys

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Summary

This document reviews the juvenile sandbar shark (<80 cm fork length) catch rates from the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) surveys conducted in Delaware and Chesapeake Bays for development of a recruitment index. Catch per unit effort (CPUE) in number of sharks per 50-hook set per hour was used to examine the relative abundance of juvenile sandbar sharks between the summer nursery seasons from 2001 to 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. The resulting index shows high variability across years that might be expected for a recruitment index, especially with a reproductive cycle of two to three years.

Introduction

In 2001, a juvenile shark bottom longline survey using a random stratified sampling plan based on depth and geographic location was initiated to assess and monitor the juvenile sandbar shark population of Delaware Bay as part of the Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) Program. Relative abundance indices from the Delaware Bay COASTPAN survey have been previously generated for juvenile sandbar sharks, including the entire footprint of the bay, during past assessments (SEDAR 11, SEDAR 21, and SEDAR 54). In 2013, the Virginia Institute of Marine Science began conducting this survey in the main stem of the lower Chesapeake Bay.

Methods

Sampling Gear and Data Collection

A 50-hook bottom longline is used at random stratified sampling stations based on depth and geographic location during the summer months from 2001 to 2024 in Delaware Bay and from 2013 to 2024 in Chesapeake Bay. The mainline consists of 305 m (1000 ft) of 0.64 cm (1/4 in) braided nylon mainline, and 50 gangions comprised of 12/0 Mustad circle hooks with barbs depressed, 50 cm of 1/16 stainless cable, and 100 cm (39 in) of 0.64 cm (1/4 inch) braided nylon line with 4/0 longline snaps. A total of 50 gangions are placed along the mainline in 6 m (20 ft) intervals. Longline soak time is approximately 30 minutes. Hooks are baited with thawed Atlantic mackerel, *Scomber scombrus* and the gear is set with weights and/or anchors to maintain position of the gear.

Station location, water and air temperatures, depth, salinity, and time of day were recorded for each set. When possible, bottom type was determined by observing bottom sediment on the anchor. The sex, weight, fork length, total length, and umbilical scar condition of all sandbar sharks were recorded. Umbilical scar condition was recorded in six categories: "umbilical remains," "fresh open," "partially healed," "mostly healed," "well healed," and none. Sandbar sharks were then tagged with a rototag and/or a nylon tipped dart tag for smaller juveniles (under 3 ft) or a steel tipped dart tag (M-tag) before release.

Data Analysis

Catch per unit effort (CPUE) in number of sharks per 50-hook set per hour was used to examine the relative abundance of juvenile sandbar sharks (<80 cm fork length) in the northeast

COASTPSAN surveys between the summer nursery seasons from 2001 to 2024. The CPUE was standardized using the Lo et al. (2002) method, which models the proportion of positive sets separately from the positive catch. Factors considered as potential influences on CPUE were: year (2001-2024), month (July and August), depth (0-5, 5-10 and 10+ m) and region (DB - Delaware Bay and CB - Chesapeake Bay). 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 (Gonzáles-Ania et al. 2001, Carlson 2002). 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. Single factors were incorporated first, followed by fixed first-level interactions. 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), in which all interactions including the "year" factor were treated as a random effect. The standardized indices of abundance were based on the year effect least square means determined from the combined binomial and lognormal components. A plot of the index re-modeled after removing the last year, 5 consecutive times, is located in Figure 5 for retrospective analysis.

Results

A total of 2801 juvenile sandbar sharks (<80cm fork length), including 949 young of the year, were caught during 2095 longline sets from 2001 to 2024 within the inlets of the Eastern Shore of Virginia and Delaware and Chesapeake Bays. Originally, the index was only developed using data from Delaware and Chesapeake Bay and with fish <80 cm fork length. After review and discussions with the Indices Working Group, another index was developed for age 0 sharks (<63.6 cm FL) and COASTSPAN sampling from Virginia's Eastern Shore was also included in the index. The size range by year and sex for these NE COASTSPAN surveys are displayed in Figure 1. The proportion of sets with positive catch, at least one sandbar shark < 80 cm FL

caught, was 43%. Young of the year proportion positive was 14%. The stepwise construction of each model and the resulting statistics for the mixed models 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). Although, an outlier was discovered in the plots of the positive catch residuals. The depth value is out of range for the Eastern Shore inlets. The model will be run again once this issue is resolved. 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.

References

Carlson J.K. 2002. A fishery-independent assessment of shark stock abundance for large coastal species in the northeast Gulf of Mexico. Panama City Laboratory Contribution Series 02-08. 26pp.

González-Ania, L.V., C.A. Brown, and E. Cortés. 2001. Standardized catch rates for yellowfin tuna (*Thunnus albacares*) in the 1992-1999 Gulf of Mexico longline fishery based upon observer programs from Mexico and the United States. Col. Vol. Sci. Pap. ICCAT 52:222-237.

Table 1. Results of the stepwise procedure for development of a recruitment index using the NE 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

FACTOR	DF	DEVIANCE	DEVIANCE	%DIFF	DELTA%	CHISQ	PR>CHI
null	202	473.5844	2.3445				
area	201	422.8943	2.104	10.258		50.69	<.0001
year	179	384.0164	2.1453	8.496		89.57	<.0001
depth	200	434.6825	2.1734	7.298		38.90	<.0001
month	201	473.5304	2.3559	-0.486		0.05	0.8162
AREA +							
depth	199	356.3643	1.7908	23.617	13.3589	66.53	<.0001
year	178	341.2095	1.9169	18.238	7.9804	81.68	<.0001
AREA + DEPTH +							
year	176	273.3856	1.5533	33.747	15.5086	82.98	<.0001
AREA + DEPTH + YEAR							
area*depth	174	237.7155	1.3662	41.727	7.980	35.67	<.0001
year*depth	130	227.0265	1.7464	25.511	-8.236	negative hessian	

FINAL MODEL: AREA + DEPTH + YEAR + AREA*DEPTH

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

Significance (Pr>Chi) of Type 3	area	year	depth	area*depth
test of fixed effects for each factor	<.0001	<.0001	0.7665	<.0001
DF	1	23	2	2
CHI SQUARE	25.06	64.22	0.53	31.38

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE	%DIFF	DELTA%	CHISQ	PR>CHI
null	359	452.2765	1.2598				
area	358	406.7791	1.1363	9.803		38.17	<.0001
year	336	403.6167	1.2012	4.652		40.98	0.0119
depth	357	440.4702	1.2338	2.064		9.52	0.0086
month	358	446.7599	1.2479	0.945		4.42	0.0356
AREA +							
depth	356	377.7236	1.0610	15.780	5.977	26.68	<.0001
year	335	365.0350	1.0897	13.502	3.699	38.98	0.0199
AREA + DEPTH +							
year	333	333.2739	1.0008	20.559	7.057	45.07	0.0039
AREA + DEPTH + YEAR +							
area*depth	331	299.0671	0.9035	28.282	7.723	38.99	<.0001
year*depth	291	285.8438	0.9823	22.027	1.468	55.27	0.0824
AREA + DEPTH + YEAR + AREA*DEPTH +							
year*depth	289	265.2708	0.9179	27.139	-1.143	43.17	0.4211

FINAL MODEL: AREA + DEPTH + YEAR + AREA*DEPTH

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

Significance (Pr>Chi) of Type 3	area	year	depth	area*depth
test of fixed effects for each factor	<.0001	0.0001	0.8691	<.0001
DF	1	23	1	1
CHI SQUARE	16.64	60.36	0.03	58.26

Table 2. Results of the stepwise procedure for development of a recruitment index using the NE 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/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	268	650.8126	2.4284				
area	266	444.4056	1.6707	31.202		206.41	<.0001
year	245	533.5178	2.1776	10.328		117.29	<.0001
depth	266	613.2214	2.3053	5.069		37.59	<.0001
month	267	650.6438	2.4369	-0.350		0.17	0.6811
AREA +							
depth	264	361.8698	1.3707	43.555	12.3538	82.54	<.0001
year	243	382.0361	1.5722	35.258	4.0562	62.37	<.0001
AREA + DEPTH +							
year	241	294.7448	1.223	49.638	14.3798	67.12	<.0001
AREA + DEPTH + YEAR							
area*depth	237	229.7626	0.9695	60.077	10.439	64.98	<.0001
year*area	220	267.8585	1.2175	49.864	0.226	negative hessian	
year*depth	195	256.3777	1.3148	45.857	-3.780	negative hessian	

FINAL MODEL: AREA + DEPTH + YEAR + AREA*DEPTH

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

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	area	depth	year	area*depth
	<.0001	0.7147	0.0237	<.0001
DF	2	2	23	4
CHI SQUARE	60.12	0.67	38.29	40.85

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
null	387	569.7578	1.4722				
area	385	429.3046	1.1151	24.256		109.82	<.0001
year	364	503.11	1.3822	6.113		48.27	0.0015
depth	385	563.1127	1.4626	0.652		4.55	0.1027
month	386	565.3516	1.4646	0.516		3.01	0.0826
AREA +							
year	362	366.2174	1.0117	31.280	7.024	61.67	<.0001
AREA + YEAR +							
year*area	341	337.8384	0.9907	32.706	1.426	31.3	0.0689

FINAL MODEL: AREA + YEAR

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

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	area	year
	<.0001	<.0001
DF	2	23
CHI SQUARE	135.32	62.36

Tables 3 and 4. NE COASTSPAN LL index results for **sandbar sharks (< 80 cm FL)** and YOY sandbar sharks (<63.6 cm FL), respectively, from 2001-2024. 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
2001	33	16	0.4848	2.5493	3.2467	1.5723	6.7040	0.3748
2002	51	20	0.3922	1.5635	1.5687	0.7847	3.1361	0.3570
2003	34	21	0.6176	4.8334	4.0870	2.2149	7.5416	0.3136
2004	45	31	0.6889	4.6297	5.0172	3.1296	8.0434	0.2393
2005	23	12	0.5217	6.8290	9.4081	4.3469	20.3621	0.4009
2006	34	15	0.4412	2.2587	2.1597	1.0113	4.6124	0.3935
2007	36	12	0.3333	0.9478	1.0021	0.4043	2.4837	0.4782
2008	20	4	0.2000	0.7788	1.1101	0.2643	4.6627	0.8207
2009	18	11	0.6111	6.9344	4.6237	2.1109	10.1279	0.4076
2010	15	5	0.3333	2.8126	2.5561	0.7293	8.9596	0.6941
2011	13	9	0.6923	7.4923	7.6392	3.4565	16.8835	0.4126
2012	27	10	0.3704	1.4919	1.7532	0.6950	4.4226	0.4886
2013	45	29	0.6444	4.3877	3.2115	1.8150	5.6826	0.2912
2014	52	29	0.5577	3.8133	1.8003	0.9528	3.4015	0.3264
2015	43	23	0.5349	2.9468	1.1308	0.5422	2.3583	0.3803
2016	44	24	0.5455	4.2251	2.0263	1.0322	3.9778	0.3471
2017	40	30	0.7500	6.0205	3.3517	1.9650	5.7168	0.2718
2018	25	15	0.6000	9.9561	5.8947	2.8842	12.0476	0.3691
2019	42	18	0.4286	3.4904	1.8517	0.8727	3.9290	0.3898
2020	5	4	0.8000	17.0000	5.8958	1.3147	26.4391	0.8694
2021	35	17	0.4722	4.1878	2.6229	1.2512	5.4983	0.3831
2022	48	11	0.2292	1.6756	0.6541	0.2413	1.7733	0.5313
2023	37	10	0.2703	1.2095	0.7656	0.2822	2.0770	0.5317
2024	56	11	0.1964	1.6498	0.6969	0.2482	1.9568	0.5526

Table 4. NE COASTSPAN LL index results for **YOY sandbar sharks (< 63.6 cm FL)**

year	nobs	obs pos	obs ppos	obs cpue	est cpue	LCL	UCL	CV
2001	33	2	0.0606	0.1640	0.4149	0.0599	2.8724	1.2447
2002	32	9	0.2813	0.8322	2.8662	1.0275	7.9954	0.5486
2003	23	12	0.5217	4.2252	9.1064	4.2208	19.6471	0.3991
2004	28	15	0.5357	2.6471	7.4054	3.7991	14.4351	0.3432
2005	15	9	0.6000	5.7381	20.1807	9.2746	43.9111	0.4039
2006	34	9	0.2647	1.4572	4.1862	1.4976	11.7016	0.5498
2007	36	8	0.2222	0.6374	1.9484	0.6284	6.0408	0.6142
2008	20	3	0.1500	0.7308	2.8032	0.5499	14.2903	0.9701
2009	18	8	0.4444	5.8418	11.1607	4.2756	29.1328	0.5087
2010	15	3	0.2000	1.6803	7.3089	1.4779	36.1464	0.9456
2011	13	6	0.4615	5.0243	13.4356	4.8283	37.3869	0.5471
2012	27	9	0.3333	1.3499	5.5380	2.1585	14.2089	0.4985
2013	56	37	0.6607	6.6057	3.6216	2.0594	6.3688	0.2880
2014	69	41	0.5942	4.3069	2.1623	1.1205	4.1726	0.3378
2015	55	28	0.5091	4.5915	1.6094	0.7126	3.6346	0.4248
2016	50	28	0.5600	4.4850	3.8654	1.9563	7.6375	0.3506
2017	47	34	0.7234	6.4734	4.6999	2.7139	8.1393	0.2798
2018	31	21	0.6774	12.4956	10.7036	5.9243	19.3384	0.3023
2019	48	21	0.4375	10.4608	6.4971	3.0008	14.0671	0.4011
2020	11	10	0.9091	27.2727	10.0546	2.9269	34.5400	0.6807
2021	41	20	0.4762	6.0912	4.7066	2.2501	9.8449	0.3819
2022	57	22	0.3860	5.5984	2.4527	1.1068	5.4351	0.4141
2023	42	15	0.3571	4.2798	2.5884	1.0679	6.2740	0.4653
2024	60	18	0.3000	3.4537	1.9794	0.8060	4.8611	0.4729

Figure 1 NE COASTSPAN sandbar shark length frequency up to 80 cm FL by sex and year on the left and only by year on the right.

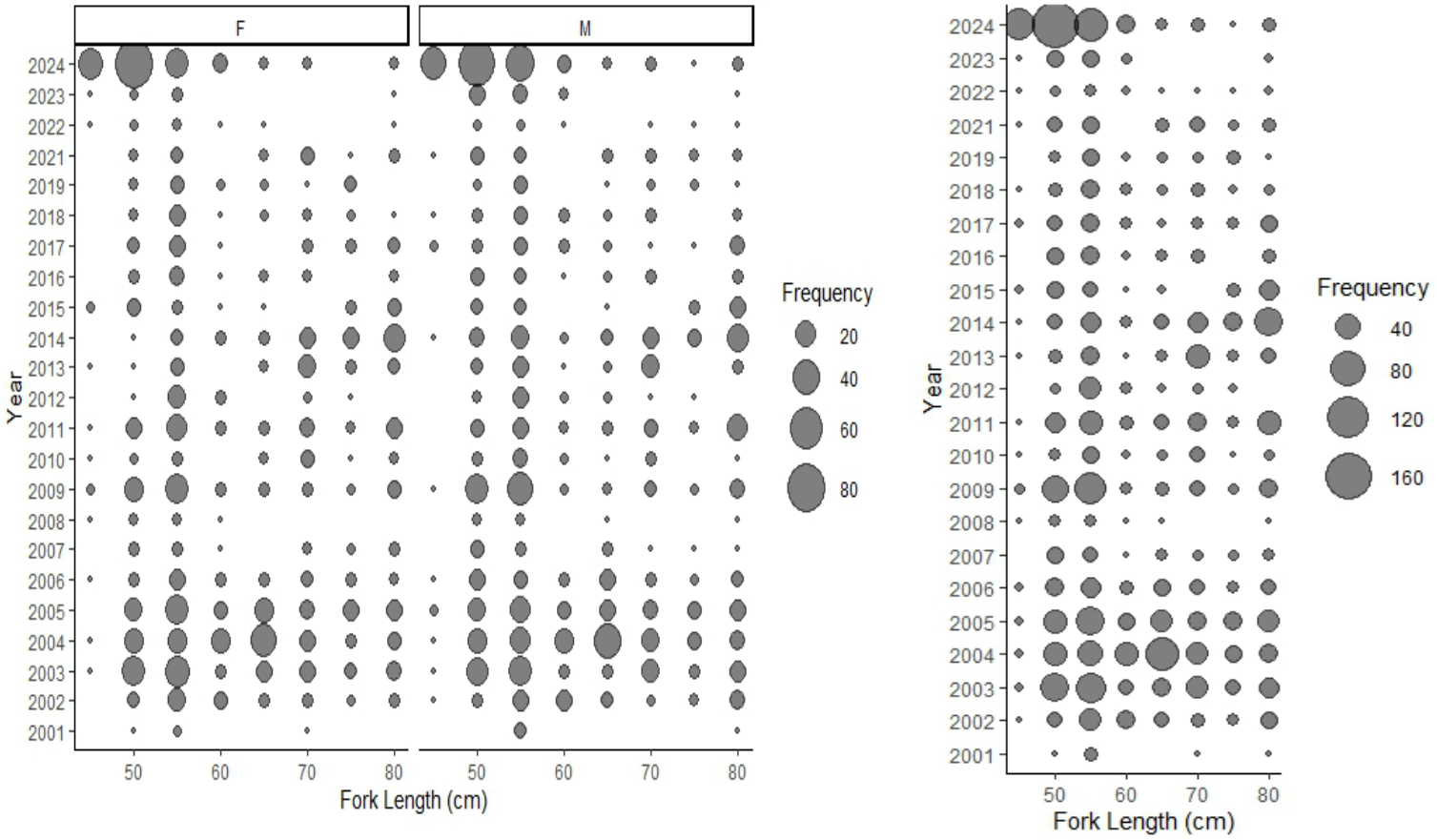
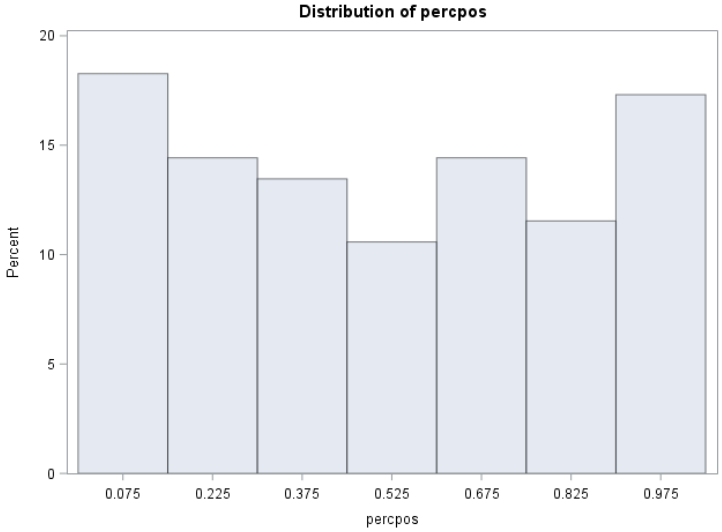
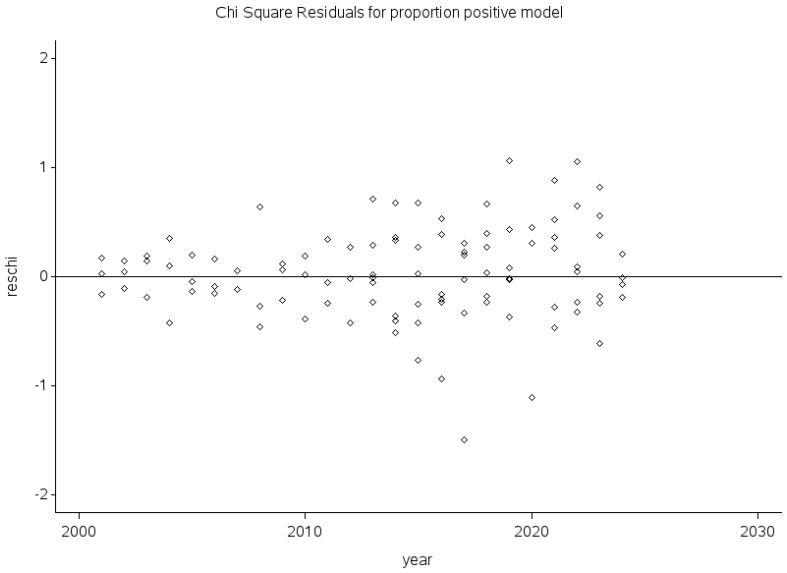
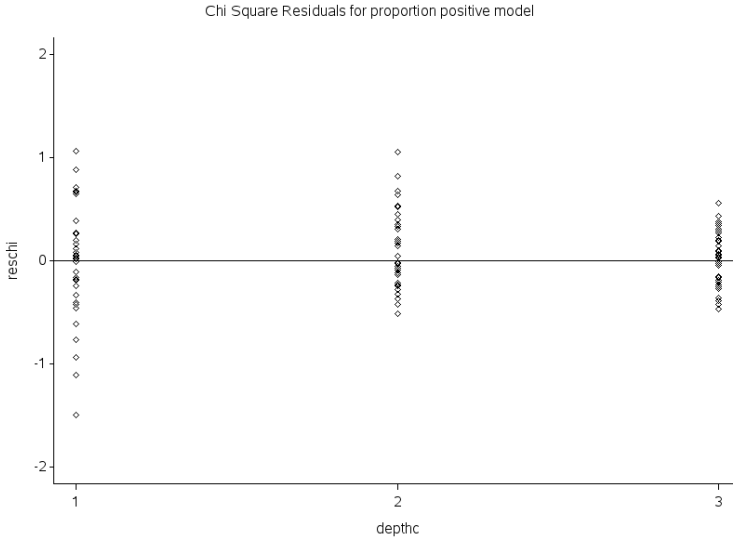


Figure 2. Diagnostic plots for the **binomial component** of the NE COASTSPAN LL catch rate model for **sandbar sharks (<80 cm FL)**.







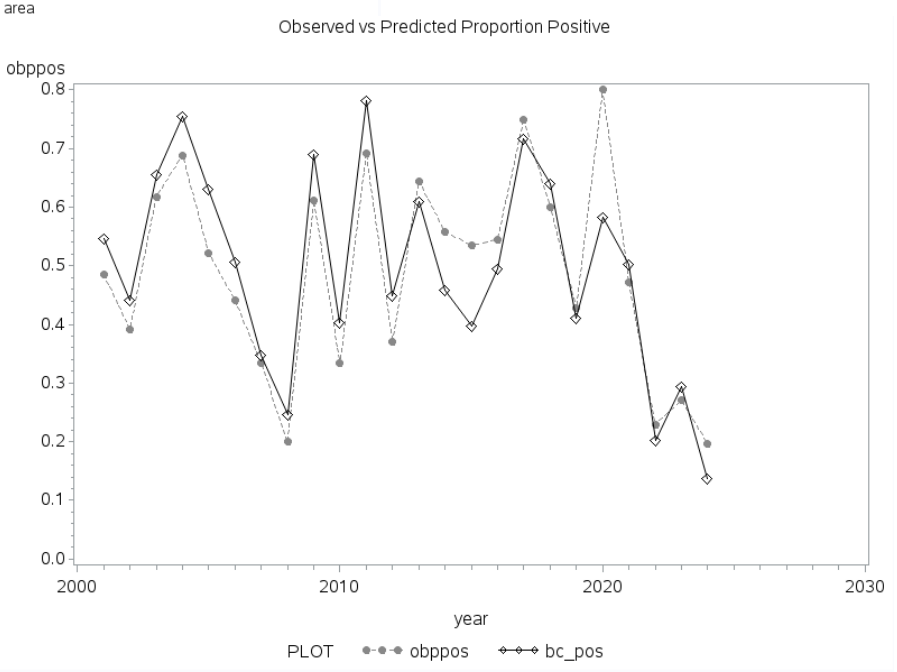


Figure 3. Diagnostic plots for the **lognormal component** of the NE COASTSPAN LL catch rate model for **sandbar sharks (<80 cm FL).**

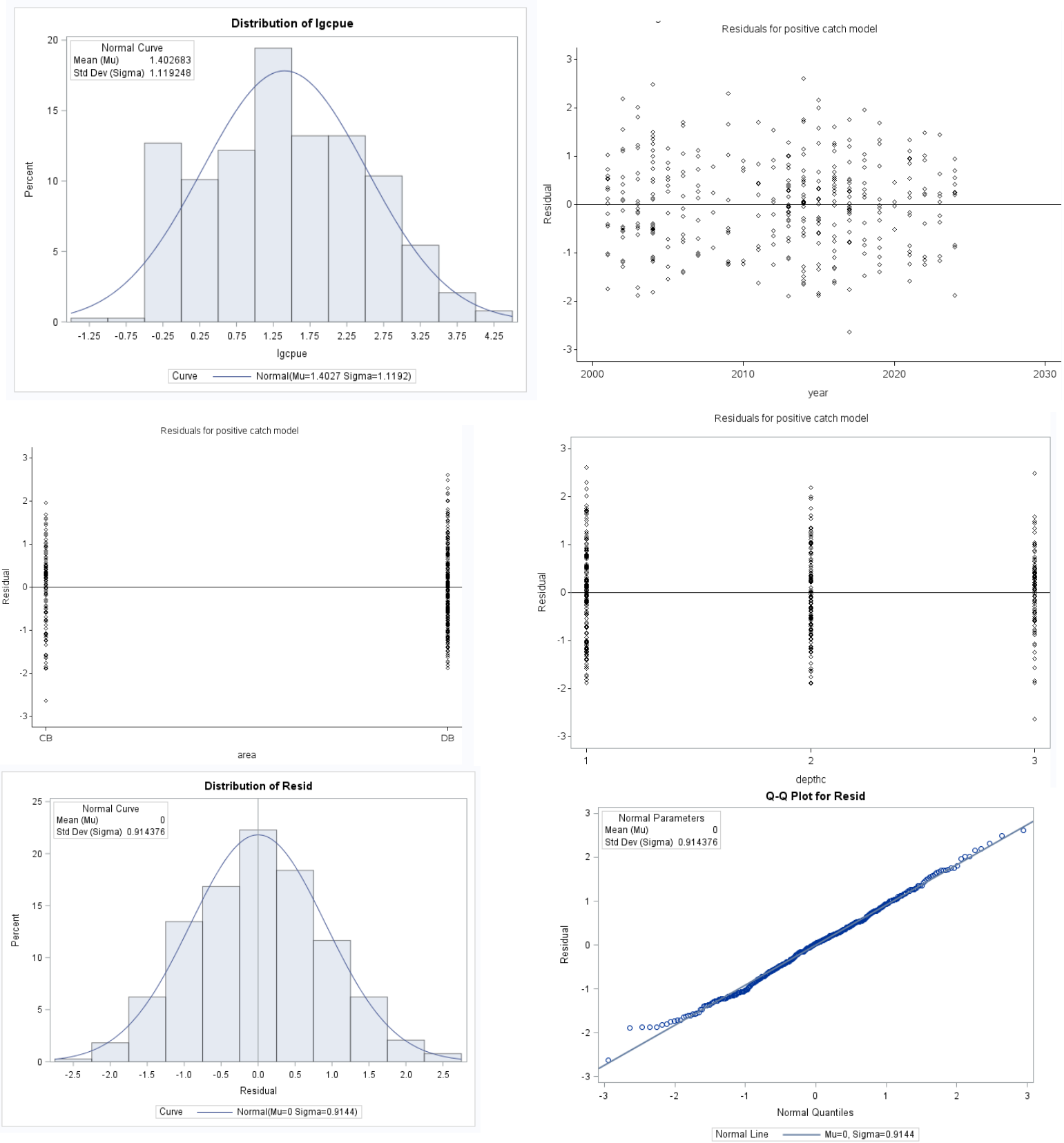


Figure 4. NE COASTSPAN index for **sandbar shark (<80 cm FL)** relative abundance (estcpue) with 95% confidence intervals (LCI0, UCI0) and overlayed with the nominal catch-per-unit-effort data. (obcpue)

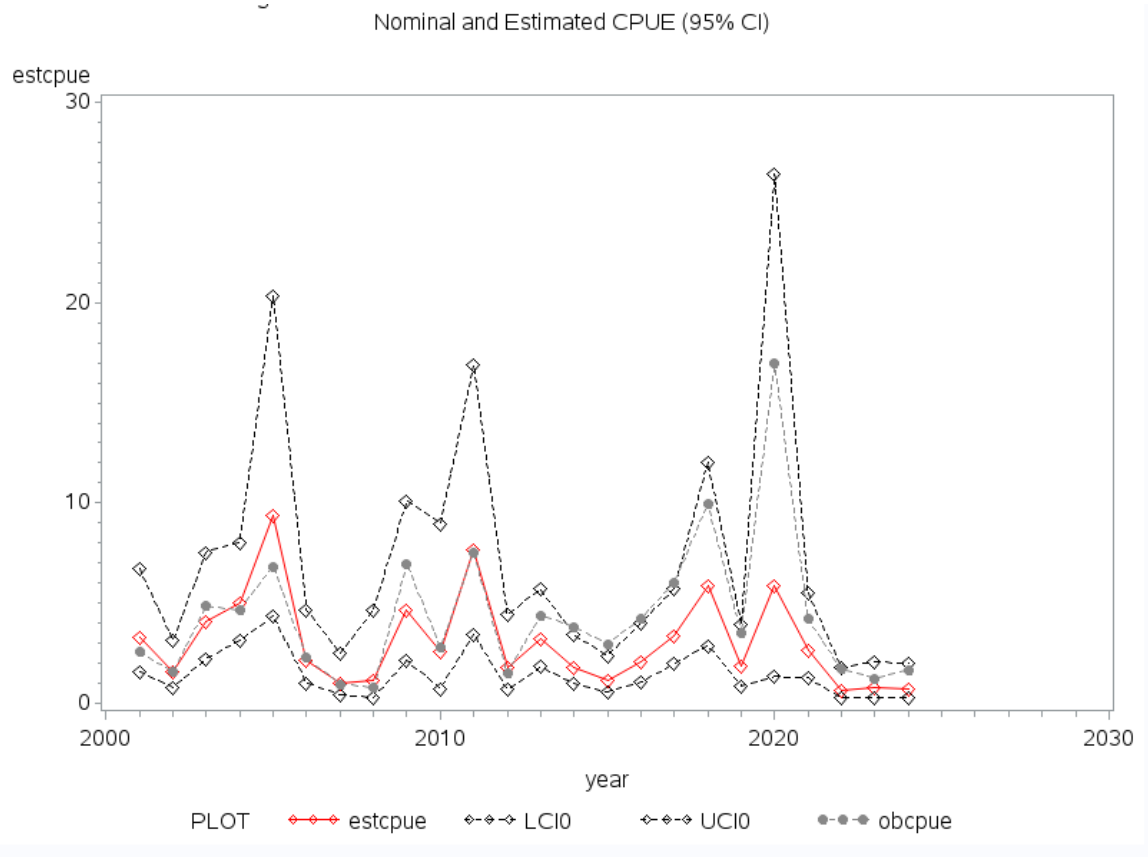


Figure 4. Retrospective analysis for NE COASTSPAN sandbar shark (<80 cm FL) index

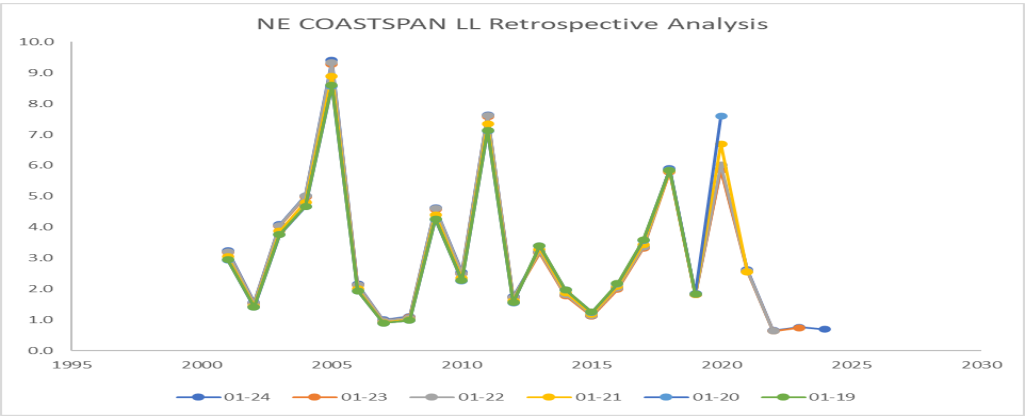
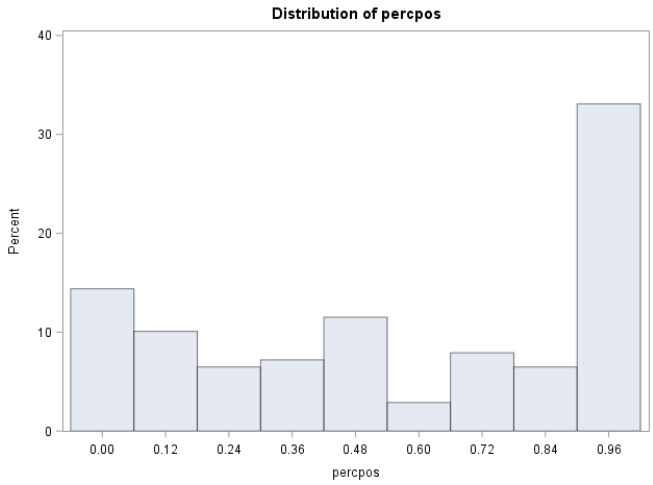
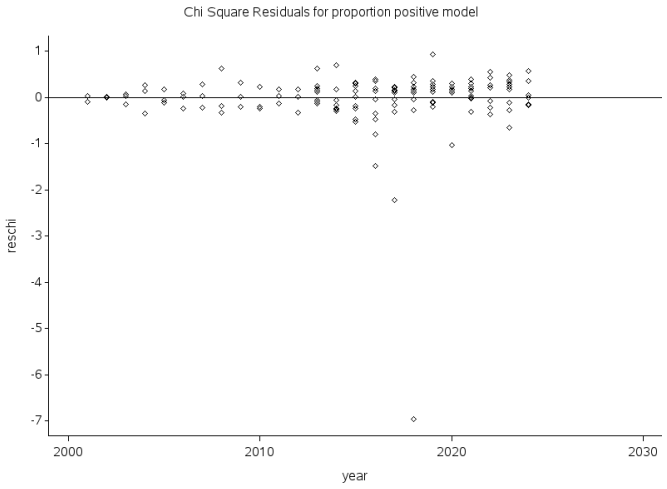
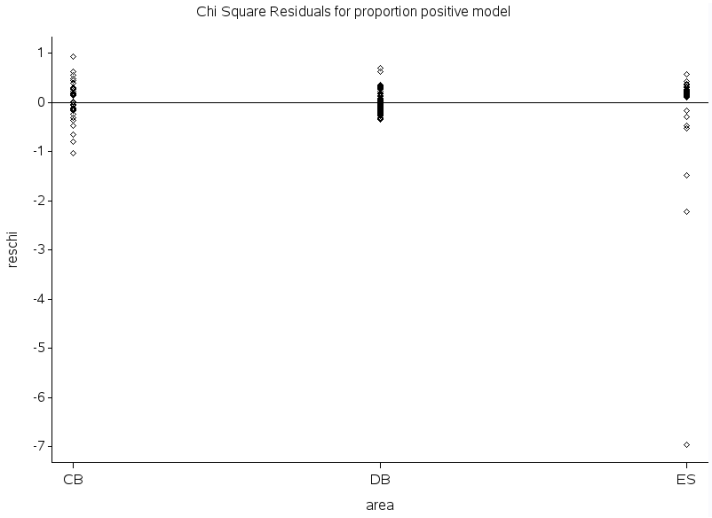
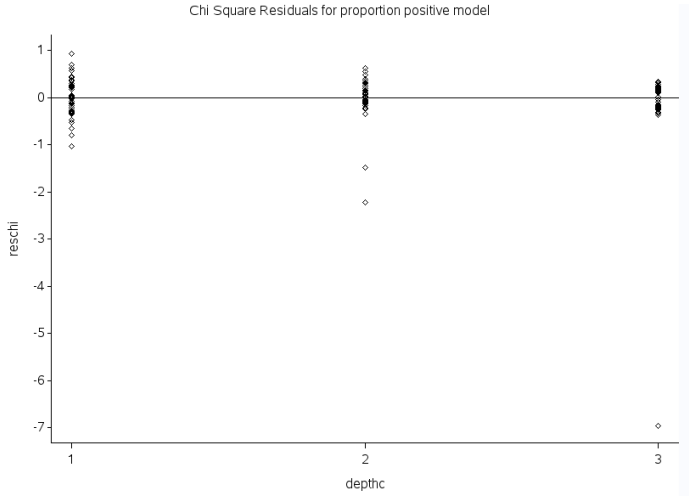


Figure 5. Diagnostic plots for the **binomial component** of the NE COASTSPAN LL catch rate model for **YOY sandbar sharks (<63.6 cm FL).**









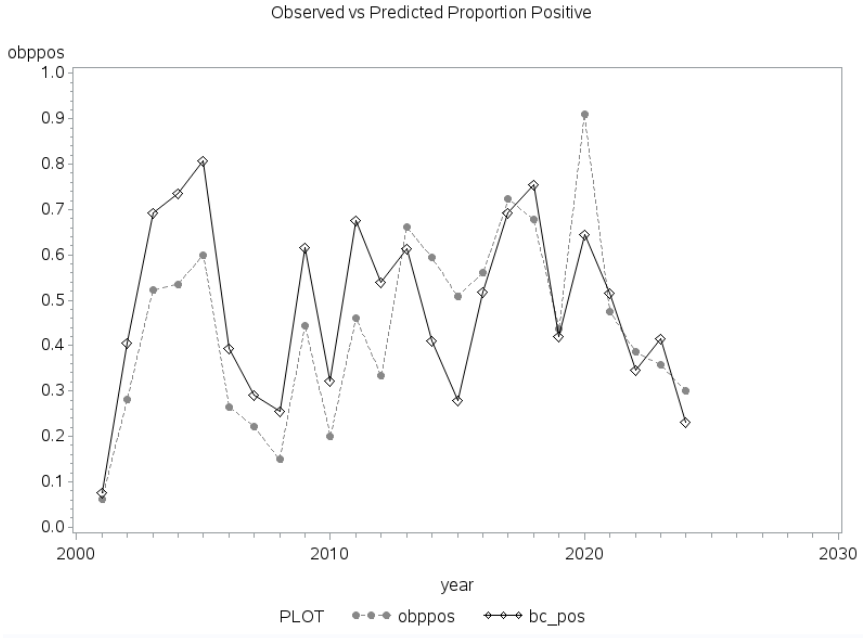
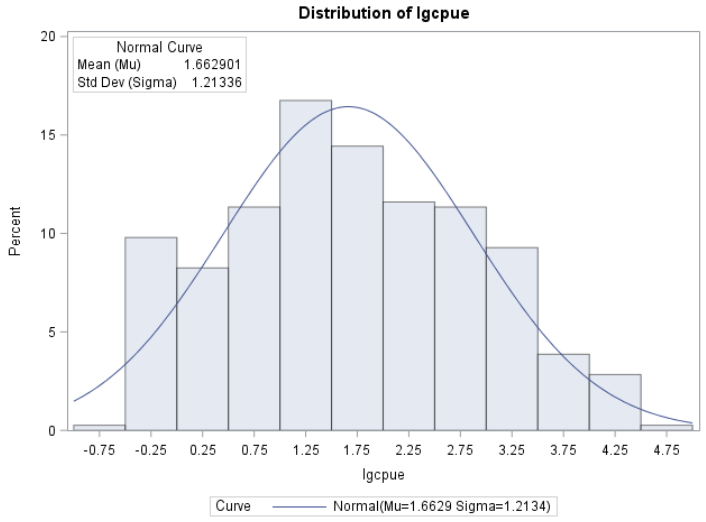
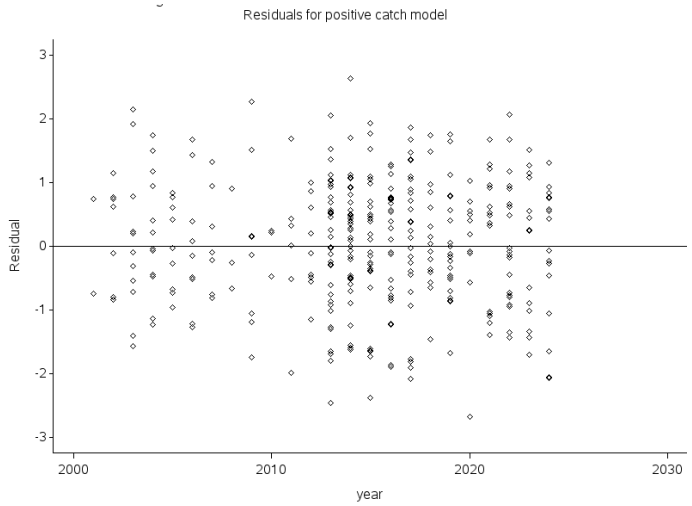
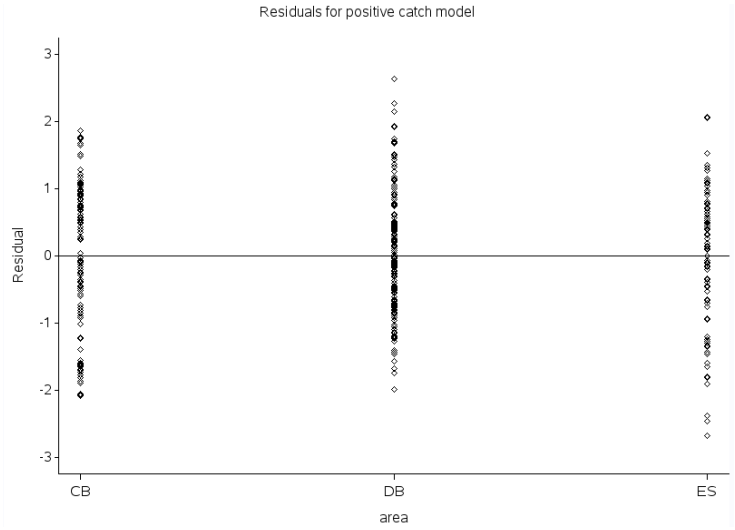
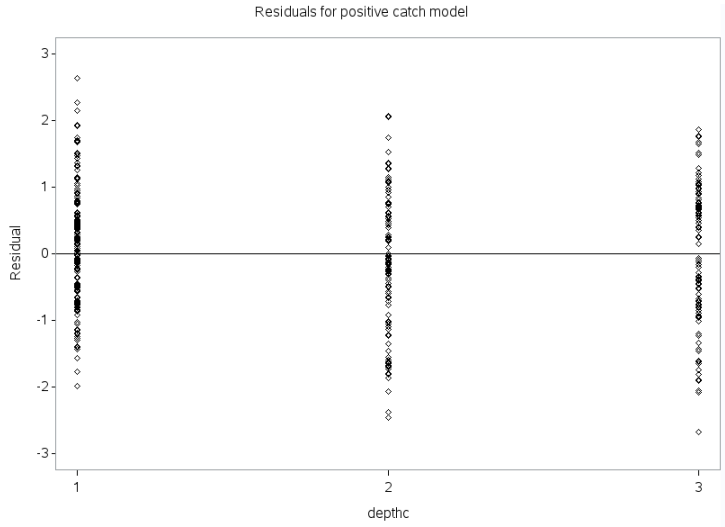


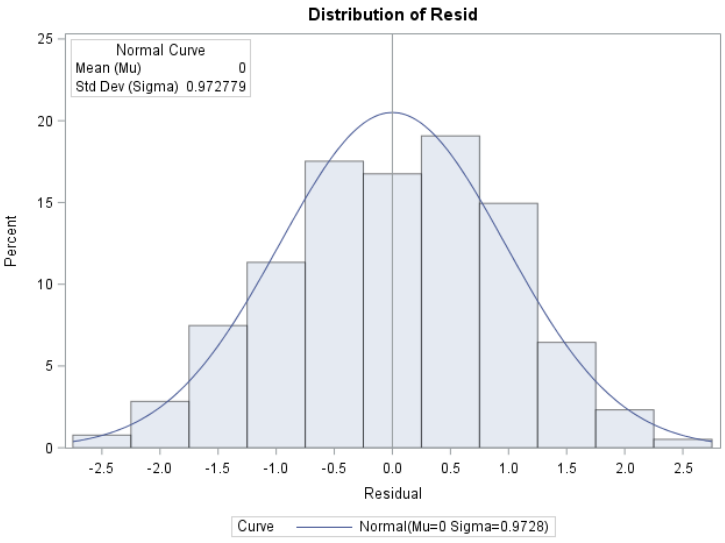
Figure 6. Diagnostic plots for the **lognormal component** of the NE COASTSPAN LL catch rate model for **YOY sandbar sharks (<63.5 cm FL).**











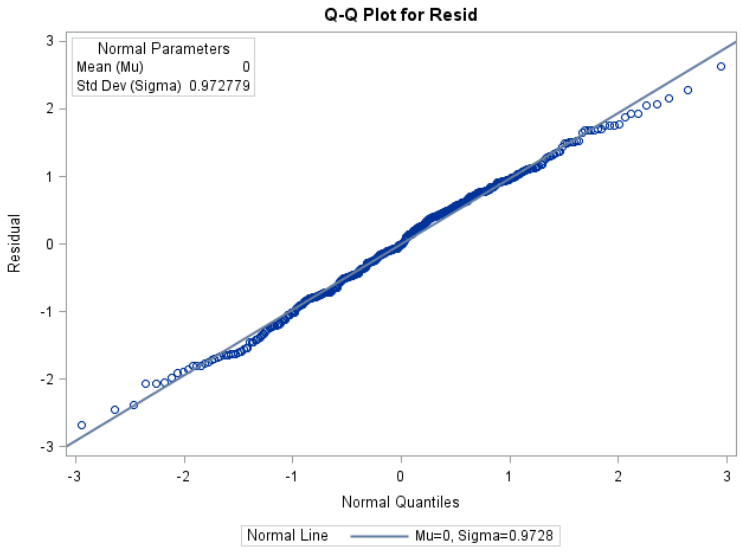


Figure 7. NE COASTSPAN index for **YOY sandbar shark (<63.6 cm FL)** relative abundance (estcpue) with 95% confidence intervals (LCI0, UCI0) and overlayed with the nominal catch-per-unit-effort data. (obcpue)

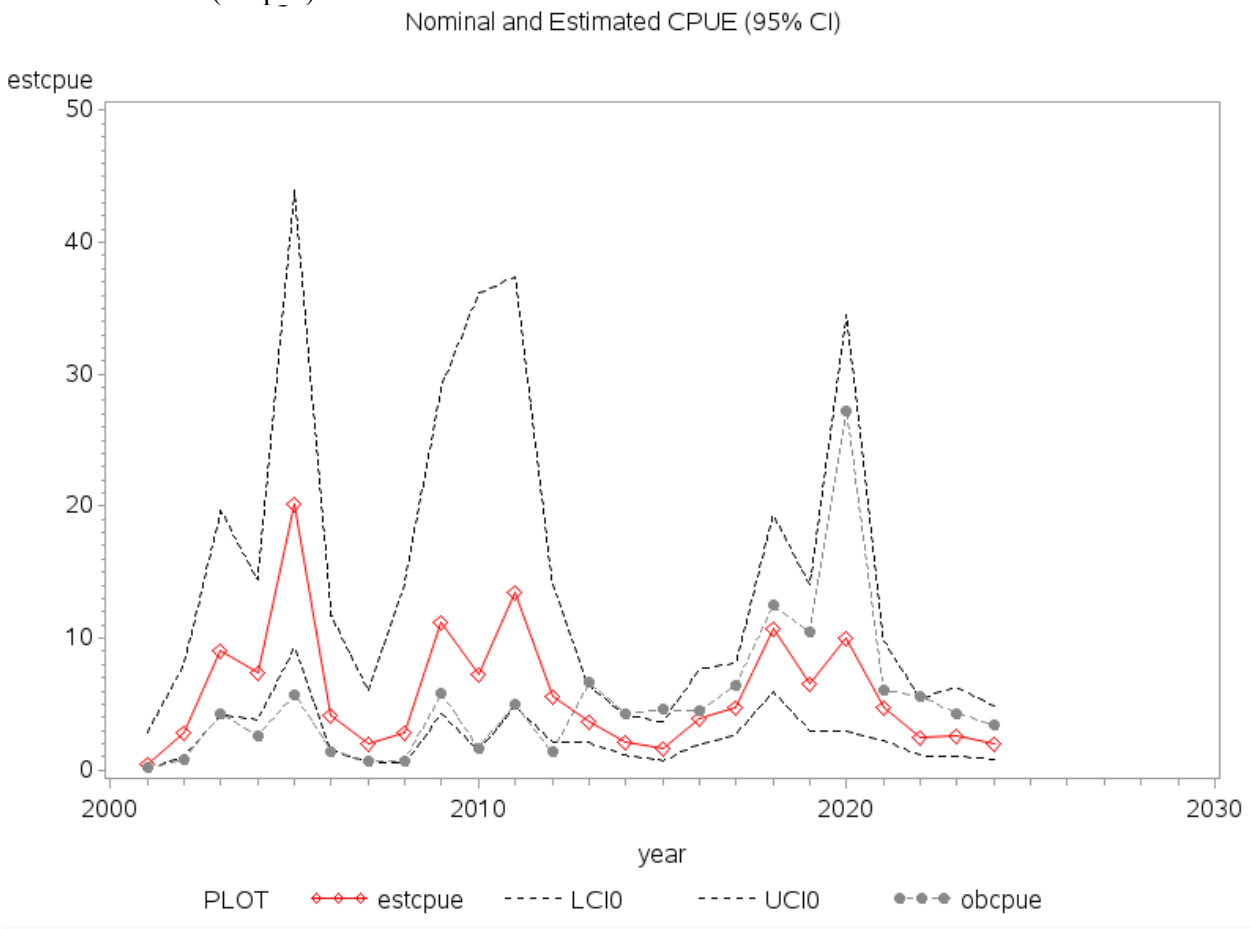


Figure 8. Retrospective analysis for NE COASTSPAN **YOY sandbar shark (<63.6 cm FL)** index