SEDAR 21 DATA WORKSHOP DOCUMENT

Standardized catch rates of sandbar and blacknose sharks from the SCDNR COASTSPAN and red drum surveys

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Summary

This document details shark catches from the South Carolina Department of Natural Resources (SCDNR), Cooperative Atlantic States Shark Pupping and Nursery (COASTSPAN) survey and the SCDNR adult red drum survey, both conducted in South Carolina's estuarine and nearshore waters from 1998-2009. Catch per unit effort (CPUE) in number of sharks per hook hour were used to examine blacknose and/or sandbar shark relative abundance for all SCDNR time series. The SCDNR red drum time series had to be analyzed in two separate time segments (1998-2006 and 2007-2009) due to a change in gear and sampling design. The CPUE for all time series was standardized using a two-step delta-lognormal approach originally proposed by Lo et al (1992) that models the proportion of positive catch with a binomial error distribution separately from the positive catch, which is modeled using a lognormal distribution. Sandbar sharks from the SCDNR COASTSPAN survey showed a fairly stable trend in relative abundance from 1998 to 2003, followed by a slight increasing trend during the mid 2000s. Sandbar sharks from the 1998-2006 SCDNR red drum survey showed a drop in abundance from 1999 to 2000 followed by a more stable trend in the 2000s and blacknose sharks appeared to be stable throughout the time series. Blacknose and sandbar sharks from the 2007-2009 SCDNR red drum survey also showed a relatively stable trend during the three year time frame this survey has been in existence.

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 addition to the estuarine areas sampled specifically for sharks, the SCDNR also samples the shark bycatch from a long-term longline survey designed to monitor adult red drum *Sciaenops ocellatus* in the coastal waters of South Carolina. This survey was modified from a fixed station to a random stratified station survey in 2007 in response to the needs of stock assessment biologists and to increase coverage along the coast. In addition, the mainline and number of hooks used for the 2007-2009 SCDNR red drum longline survey were reduced to one third of the original mainline length and hook number per set. For these reasons, the SCDNR red drum longline survey was analyzed as two separate time series (1998-2006 and 2007-2009). Relative abundance indices from the SCDNR red drum survey have been previously generated for blacknose sharks covering the time period from 1998 to 2005 (McCandless et al. 2007). In this document, the time series is updated with data through 2006, including recovered depth data.

Methods

Sampling design

SC COASTSPAN estuarine sampling locations were selected in the lower reaches of estuaries in depths which would facilitate the deployment and retrieval of gillnets and hand deployed longlines (i.e. current velocity, tidal range, vessel traffic). All estuarine longline sampling occurred inside of inlets and sampling locations varied with regard to distance from nearshore waters. Estuarine sampling was conducted primarily from April through October with the majority of the effort occurring between May and September. Nearshore sampling stations were those previously selected for adult red drum sampling. Nearshore sampling occurred from immediately outside of the surf zone to 8 km offshore with depths ranging from 3–15 m. These sites were primarily live-bottom areas with low relief, consisting of rock or marl outcrops that were encrusted with sessile invertebrates such as sponges, gorgonians and bryozoans. Nearshore sampling occurred throughout the year with the exception of February; however, nearshore sampling was most intense from September through mid-December. The locations of the SC

COASTSPAN and the 1998-2006 SCDNR red drum fixed estuarine and nearshore sampling areas are shown in Figure 1.

In 2007, GADNR red drum sampling protocol was changed to increase geographical and seasonal coverage. Thirty sites are randomly selected from a predetermined list of sites (40-100 sites/strata) during each sampling period (2- month periods: March/April. May/June, July/August, September/October, November/December). Each of four strata (Winyah Bay, Charleston Harbor, St. Helena Sound and Port Royal Sound) is sampled once during each time period (Figure 2). Specific sampling locations within each stratum have been identified and chosen due to bottom type, depth, and in some cases from previous sampling or suggestions from local charter captains.

Sampling gear and data collection

The SC COASTSPAN longline gear consisted of 305 m of 0.64 cm braided nylon mainline which supported the use of 50 gangions. Each gangion consisted of a 0.5 m, 91 kg test monofilament leader, size120 stainless steel longline snap, 4/0 swivel and a 12/0 circle hook. Prior to the 2000 sampling year the SC COASTSPAN longline was allowed to soak for 45-60 minutes and then retrieved. After retrieval the gear was either reset or moved to a new location, depending on catch. High bait loss was noted on most sets and therefore the sampling strategy was modified in 2000 and the longline was under run at 15-20 minute intervals. SCDNR red drum longline gear consisted of a 272 kg test monofilament mainline that was 1829 m in length for the 1998-2006 time series and 610 m for the 2007-2009 time series and both time series had 30.5 m buoy lines attached at each end. The mainline for both red drum time series was equipped with stop sleeves at 30.5 m intervals to prevent gangions from sliding together when a large fish was captured. The gangions were the same as those used on the SC COASTSPAN longline with the exception that 14/0 and 15/0 circle hooks were employed. For the 1998-2006 SCDNR red drum time series a set consisted of 120 hooks, and for the 2007-2009 time series a set consisted of 40 hooks. Soak times for red drum longline sets were limited to 45 minutes unless conditions or events dictated otherwise.

Station location, water temperature, salinity, and time of day were recorded for each set for all gear types. 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 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 hook hour were used to examine blacknose and/or sandbar shark relative abundance for all SCDNR time series. The CPUEs were standardized using the Lo et al. (2002) method which models the proportion of positive sets separately from the positive catch. This analysis was done for the following dependent variables: SC COASTSPAN sandbar shark CPUE, 1998-2006 SCDNR red drum survey sandbar shark CPUE and 1998-2006 GADNR red drum survey blacknose shark CPUE, 2007-2009 SCDNR red drum survey sandbar shark CPUE and 2007-2009 SCDNR red drum survey blacknose CPUE. Factors considered as potential influences on all SCDNR longline survey sets were: year (1998–2009; 1998-2006; 2007-2009), month (April – October; April-December; April-December), depth (0-5 , >5 m; 0-5 , 6-10, 11-20, 21+ m; 0-9, 10+ m), and area (each of the estuaries, off beaches and nearshore stations) for SC COASTSPAN, the 1998-2006 red drum time series and the 2007-2009 red drum time series, respectively. 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.

Results

SC COASTSPAN survey – sandbar sharks

A total of 794 sandbar sharks were caught during 502 longline sets from 1998 to 2009. The size range of juvenile sandbar sharks caught by year is displayed in Figure 3. The proportion of sets with positive catch (at least one sandbar shark caught) was 45%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 1. Model diagnostic plots reveal that the model fit is acceptable (Figures 4a and 4b). 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.

SCDNR red drum survey (1998-2006) – sandbar sharks

A total of 609 sandbar sharks were caught during 538 longline sets from 1998 to 2006. The size range of juvenile sandbar sharks caught by year is displayed in Figure 6. The proportion of sets with positive catch (at least one sandbar shark caught) was 32%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 3. Model diagnostic plots reveal that the model fit is acceptable (Figures 7a and 7b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 4 and are plotted by year in Figure 8.

SCDNR red drum survey (1998-2006) – blacknose sharks

A total of 655 sandbar sharks were caught during 538 longline sets from 1998 to 2006. The size range of juvenile sandbar sharks caught by year is displayed in Figure 9. The proportion of sets with positive catch (at least one sandbar shark caught) was 33%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 5. Model diagnostic plots reveal that the model fit is acceptable (Figures 10a and 10b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 6 and are plotted by year in Figure 11.

SCDNR red drum survey (2007-2009) – sandbar sharks

A total of 570 sandbar sharks were caught during 789 longline sets from 2007 to 2009. The size range of juvenile sandbar sharks caught by year is displayed in Figure 12. The proportion of sets with positive catch (at least one sandbar shark caught) was 30%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table

7. Some model diagnostic plots reveal that the model fit may be acceptable, but the histogram for the lognormal model residuals on positive catch rates and the Q-Q plot indicates that the positive catch data are not normally distributed (Figures 13a and 13b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 8 and are plotted by year in Figure 14.

SCDNR red drum survey (2007-2009) – blacknose sharks

A total of 381 sandbar sharks were caught during 789 longline sets from 2007 to 2009. The size range of juvenile sandbar sharks caught by year is displayed in Figure 15. The proportion of sets with positive catch (at least one sandbar shark caught) was 22%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 9. Some model diagnostic plots reveal that the model fit may be acceptable, but the histogram for the lognormal model residuals on positive catch rates and the Q-Q plot indicates that the positive catch data are not normally distributed (Figures 16a and 16b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 10 and are plotted by year in Figure 17.

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Table 1. Results of the stepwise procedure for development of the catch rate model for sandbar sharks caught during the SC COASTSPAN survey. %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	475	653.2726	1.3753				
YEAR	464	549.1404	1.1835	13.9460	12.5735	104.13	<.0001
AREA	471	598.5120	1.2707	7.6056		54.76	<.0001
DEPTH	474	605.1103	1.2766	7.1766		48.16	<.0001
MONTH	470	635.0041	1.3511	1.7596		18.27	0.0026
YEAR +							
AREA	460	509.9193	1.1085	19.3994	5.4534	39.22	<.0001
MONTH	459	528.5899	1.1516	16.2655		20.55	0.0001
DEPTH	463	548.7186	1.1851	13.8297		0.42	0.5160
YEAR + AREA +							
MONTH	455	484.8666	1.0656	22.5187	3.1193	25.05	0.0001
YEAR + AREA + MONTH +							
YEAR*AREA	434	426.979	0.9838	28.4665	5.9478	Negative of Hessian not positive definite	
YEAR*MONTH	425	398.8752	0.9385	31.7603		Negative of Hessian not positive definite	
AREA*MONTH	442	462.4172	1.0462	23.9293		Negative of Hessian not positive definite	

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
YEAR + AREA + MONTH	273.0	275.1	271.0

Type 3 Test of Fixed Effects for Final Model = MONTH + YEAR

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	YEAR	AREA	MONTH
	0.0003	0.0015	0.0896
DF	11	4	6
CHI SQUARE	34.96	17.60	10.96

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	209	197.5812	0.9454				
YEAR	198	145.5246	0.7350	22.2551	9.5286	64.22	<.0001
AREA	205	174.6437	0.8519	9.8900		25.91	<.0001
MONTH	204	184.0995	0.9024	4.5483		14.84	0.0111
DEPTH	208	197.5701	0.9499	-0.4760		0.01	0.9133
YEAR +							
MONTH	193	133.3013	0.6907	26.9410	4.6858	18.42	0.0025
AREA	194	139.8931	0.7211	23.7254		8.29	0.0816
YEAR + MONTH							
YEAR*MONTH	172	108.5645	0.6312	33.2346	6.2936	43.11	0.0030

MIXED MODELS	AIC	BIC	(-2) Res Log Likelihood
YEAR + MONTH	528.4	531.8	526.4
*YEAR + MONTH + YEAR*MONTH*	*497.4*	*500.7*	*495.4*

Type 3 Test of Fixed Effects for Final Model = YEAR + MONTH + YEAR*MONTH

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	YEAR	MONTH	YR*MON
	<.0001	0.0568	0.8483
DF	11	6	21
CHI SQUARE	39.38	12.24	14.48

Table 2. SC COASTSPAN survey sandbar shark analysis number of sets per year (obs n), 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	LCI	UCI	CV
1998	11	5	0.4545	0.3836	0.6336	0.1794	2.2372	0.6990
1999	12	7	0.5833	0.3854	0.5532	0.1714	1.7855	0.6399
2000	42	5	0.1304	0.0814	0.0947	0.0197	0.4559	0.9240
2001	58	6	0.1034	0.0516	0.0493	0.0112	0.2164	0.8537
2002	31	6	0.1818	0.2056	0.2007	0.0451	0.8937	0.8641
2003	41	11	0.2683	0.4093	0.2796	0.0752	1.0388	0.7338
2004	41	24	0.5854	1.8583	1.5781	0.7783	3.1998	0.3648
2005	91	49	0.5385	1.0072	0.9608	0.5803	1.5909	0.2562
2006	73	42	0.5753	1.4055	1.6053	1.0108	2.5493	0.2344
2007	41	26	0.6429	1.8729	1.8269	0.9827	3.3961	0.3176
2008	31	22	0.7097	1.8355	1.8113	0.8731	3.7577	0.3774
2009	30	20	0.6667	1.2882	1.2390	0.6008	2.5551	0.3741

Table 3. Results of the stepwise procedure for development of the catch rate model for sandbar sharks caught during the 1998-2006 SCDNR red drum survey. %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	537	680.1750	1.2666				
MONTH	527	625.9708	1.1878	6.2214	6.2214	54.20	<.0001
YEAR	529	646.0160	1.2212	3.5844		34.16	<.0001
DEPTH	534	665.0674	1.2454	1.6738		15.11	0.0017
AREA	533	666.9135	1.2512	1.2159		13.26	0.0101
MONTH +							
YEAR	519	601.8749	1.1597	8.4399	2.219	24.10	0.0022
DEPTH	524	616.3943	1.1763	7.1293		9.58	0.0225
AREA	523	615.6896	1.1772	7.0583		10.28	0.0359
MONTH + YEAR +							
AREA	515	589.2835	1.1442	9.6605	1.221	13.59	0.0087
DEPTH	516	596.5125	1.1560	8.7320		5.36	0.1471
MONTH + YEAR + AREA +							
MONTH*YEAR	464	497.8544	1.0730	15.2850	8.156	Negative of Hessian not positive definite	
MONTH*AREA	507	577.3255	1.1387	10.0979		Negative of Hessian not positive definite	
YEAR*AREA	508	577.53	1.1369	10.2424		Negative of Hessian not positive definite	

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + YEAR + AREA	581.8	584.7	579.8

Type 3 Test of Fixed Effects for Final Model = MONTH + YEAR + AREA

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	MONTH	YEAR	AREA
	0.0336	0.0182	0.0507
DF	8	8	4
CHI SQUARE	16.68	18.43	9.45

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	174	170.3446	0.9790				
YEAR	166	113.1114	0.6814	30.3984	30.3984	71.65	<.0001
MONTH	166	130.5255	0.7863	19.6834		46.59	<.0001
DEPTH	171	152.7373	0.8932	8.7640		19.09	0.0003
AREA	170	161.4387	0.9496	3.0031		9.40	0.0519
YEAR +							
MONTH	158	94.4999	0.5981	38.9070	8.5087	31.46	0.0001
DEPTH	163	111.9394	0.6867	29.8570		1.82	0.6100
YEAR + MONTH +							
YEAR*MONTH	130	76.6291	0.5895	39.7855	0.8784	36.68	0.1260

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
YEAR + MONTH	438.1	441.2	436.1

Type 3 Test of Fixed Effects for Final Model = YEAR + MONTH

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	YEAR	MONTH
	0.0063	<.0001
DF	8	8
CHI SQUARE	21.35	32.64

Table 4. 1998-2006 SCDNR red drum survey sandbar shark analysis number of sets per year (obs n), 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	LCI	UCI	CV
1998	75	15	0.2000	0.0804	0.1400	0.0579	0.3387	0.4641
1999	43	17	0.3953	0.2948	0.5948	0.2997	1.1807	0.3531
2000	62	10	0.1613	0.0457	0.0576	0.0206	0.1610	0.5493
2001	41	13	0.3171	0.2907	0.3497	0.1437	0.8509	0.4676
2002	60	19	0.3115	0.2869	0.2307	0.1064	0.5001	0.4018
2003	83	21	0.2500	0.1931	0.1542	0.0761	0.3125	0.3646
2004	52	24	0.4643	0.4869	0.3376	0.1903	0.5990	0.2926
2005	38	14	0.3684	0.1177	0.1549	0.0688	0.3483	0.4226
2006	84	41	0.4824	0.3820	0.2793	0.1672	0.4665	0.2607

Table 5. Results of the stepwise procedure for development of the catch rate model for blacknose sharks caught during the 1998-2006 SCDNR red drum survey. %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	537	684.4262	1.2745				
MONTH	527	600.8656	1.1402	10.5430	10.5430	83.56	<.0001
AREA	533	665.5546	1.2487	2.0275		18.87	0.0008
DEPTH	534	667.6558	1.2503	1.9023		16.77	0.0008
YEAR	529	672.6493	1.2715	0.2344		11.78	0.1614
MONTH +							
DEPTH	524	563.2135	1.0748	15.6686	5.1256	37.65	<.0001
YEAR	519	580.1513	1.1178	12.2956		20.71	0.0079
AREA	523	578.1993	1.1055	13.2592		Negative of Hessian not positive definite	
MONTH * DEPTH							
YEAR	516	549.9144	1.0657	16.3833	0.7147	13.30	0.1020

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + DEPTH + YEAR	652.1	655.0	650.1

Type 3 Test of Fixed Effects for Final Model = MONTH + YEAR

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	MONTH	DEPTH	YEAR
DF	8	3	8
CHI SQUARE	30.53	15.46	7.03

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	175	145.8581	0.8335				
YEAR	167	100.9647	0.6046	27.4628	30.3984	64.74	<.0001
DEPTH	172	138.4835	0.8051	3.4000		9.13	0.0276
MONTH	167	137.6114	0.8240	1.1343		10.24	0.2484
AREA	172	142.6379	0.8293	0.5021		3.93	0.2692
YEAR +							
DEPTH	164	98.7869	0.6024	27.7243	0.2614	3.84	0.2795

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
YEAR	411.6	414.7	409.6

Type 3 Test of Fixed Effects for Final Model = YEAR

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	YEAR
DF	8
CHI SQUARE	22.78

Table 6. 1998-2006 SCDNR red drum survey blacknose shark analysis number of sets per year (obs n), 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	LCI	UCI	CV
1998	75	25	0.3333	0.1914	0.2038	0.1174	0.3538	0.2812
1999	43	11	0.2558	0.2035	0.2782	0.1275	0.6069	0.4054
2000	62	27	0.4355	0.1411	0.1774	0.1100	0.2860	0.2423
2001	41	13	0.3171	0.1518	0.1680	0.0856	0.3299	0.3472
2002	60	24	0.3934	0.3388	0.3419	0.2089	0.5594	0.2500
2003	83	34	0.4048	0.3040	0.3574	0.2365	0.5401	0.2087
2004	52	14	0.2679	0.1628	0.1307	0.0622	0.2743	0.3839
2005	38	7	0.1842	0.1686	0.1458	0.0538	0.3949	0.5309
2006	84	24	0.2824	0.1506	0.1607	0.0909	0.2843	0.2910

Table 7. Results of the stepwise procedure for development of the catch rate model for sandbar sharks caught during the 2007-2009 SCDNR red drum survey. %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	410	451.5068	1.1012				
MONTH	401	421.6611	1.0515	4.5133	4.5133	29.85	0.0005
AREA	407	441.0563	1.0837	1.5892		10.45	0.0151
DEPTH	409	450.8444	1.1023	-0.0999		0.66	0.4157
YEAR	408	449.9959	1.1029	-0.1544		1.51	0.4698
MONTH +							
AREA	398	407.6208	1.0242	6.9924	7.1467	14.04	0.0029
YEAR	399	420.1161	1.0529	4.3861		1.54	0.4619
MONTH + AREA +							
YEAR	396	405.6727	1.0244	6.9742	-0.0182	1.95	0.3775

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + AREA + YEAR	233.6	235.7	231.6

Type 3 Test of Fixed Effects for Final Model = MONTH + AREA + YEAR

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	MONTH	AREA	YEAR
DF	7	3	2
CHI SQUARE	24.15	13.57	1.91

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	96	38.9391	0.4056				
MONTH	89	31.6295	0.3554	12.3767	12.3767	20.17	0.0052
AREA	93	37.6474	0.4048	0.1972		3.27	0.3515
DEPTH	95	38.2193	0.4023	0.8136		1.81	0.1785
YEAR	94	37.7418	0.4015	1.0108		3.03	0.2199
MONTH +							
YEAR	87	31.3563	0.3604	11.1440	10.1331	0.84	0.6566

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + YEAR	172.7	175.2	170.7

Type 3 Test of Fixed Effects for Final Model = YEAR

Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	MONTH	YEAR
DF	7	2
CHI SQUARE	17.37	0.18

Table 8. 2007-2009 SCDNR red drum survey sandbar shark analysis number of sets per year (obs n), 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	LCI	UCI	CV
2007	211	64	0.3019	0.6976	0.3160	0.1616	0.6178	0.3448
2008	335	105	0.3134	0.6889	0.4709	0.3050	0.7270	0.2198
2009	243	71	0.2922	0.5180	0.4602	0.2756	0.7685	0.2606

Table 9. Results of the stepwise procedure for development of the catch rate model for blacknose sharks caught during the 2007-2009 SCDNR red drum survey. %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	410	405.1570	0.9882				
AREA	407	391.5926	0.9621	2.6355	2.6355	13.56	0.0036
YEAR	408	397.8015	0.9750	1.3342		7.36	0.0253
DEPTH	409	403.4827	0.9865	0.1698		1.67	0.1957
MONTH	401	340.2775	0.8486	14.1284		Negative of Hessian not positive definite	
AREA + YEAR	405	383.4999	0.9469	4.1768	1.5413	8.09	0.0175
AREA + YEAR + AREA*YEAR	399	379.9474	0.9522	3.6368	-0.5400	3.55	0.7370

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
AREA + YEAR	311.5	313.8	309.5

Type 3 Test of Fixed Effects for Final Model = AREA + YEAR

	AREA	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	0.0929	0.1013
DF	3	2
CHI SQUARE	6.42	4.58

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	79	35.5030	0.4494				
YEAR	77	30.0568	0.3903	13.1412	13.1412	13.32	0.0013
AREA	76	32.2099	0.4238	5.6943		7.79	0.0506
DEPTH	78	34.1198	0.4374	2.6639		3.18	0.0746
MONTH	72	32.7540	0.4549	-1.2264		6.45	0.4886

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
YEAR	164.6	167.0	162.6

Type 3 Test of Fixed Effects for Final Model= YEAR

	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	0.0758
DF	2
CHI SQUARE	5.16

Table 10. 2007-2009 SCDNR red drum survey blacknose shark analysis number of sets per year (obs n), 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	LCI	UCI	CV
2007	211	64	0.3019	0.6976	0.3160	0.1616	0.6178	0.3448
2008	335	105	0.3134	0.6889	0.4709	0.3050	0.7270	0.2198
2009	243	71	0.2922	0.5180	0.4602	0.2756	0.7685	0.2606

Figure 1. SCDNR COASTSPAN and red drum fixed nearshore and estuarine sampling stations

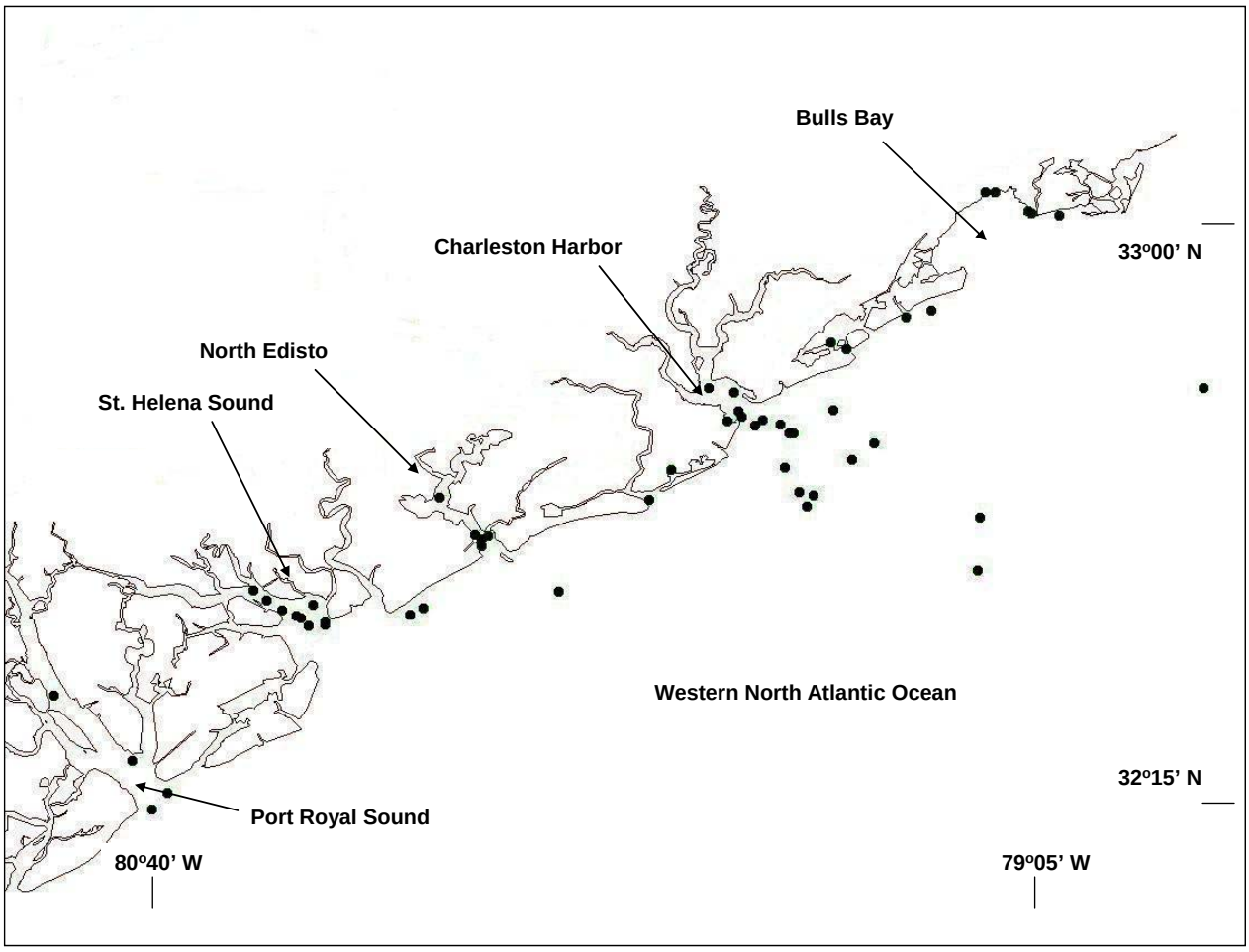


Figure 2. Sampling locations for the 2007-2009 GADNR red drum longline survey (SEDAR-18-DW-13).

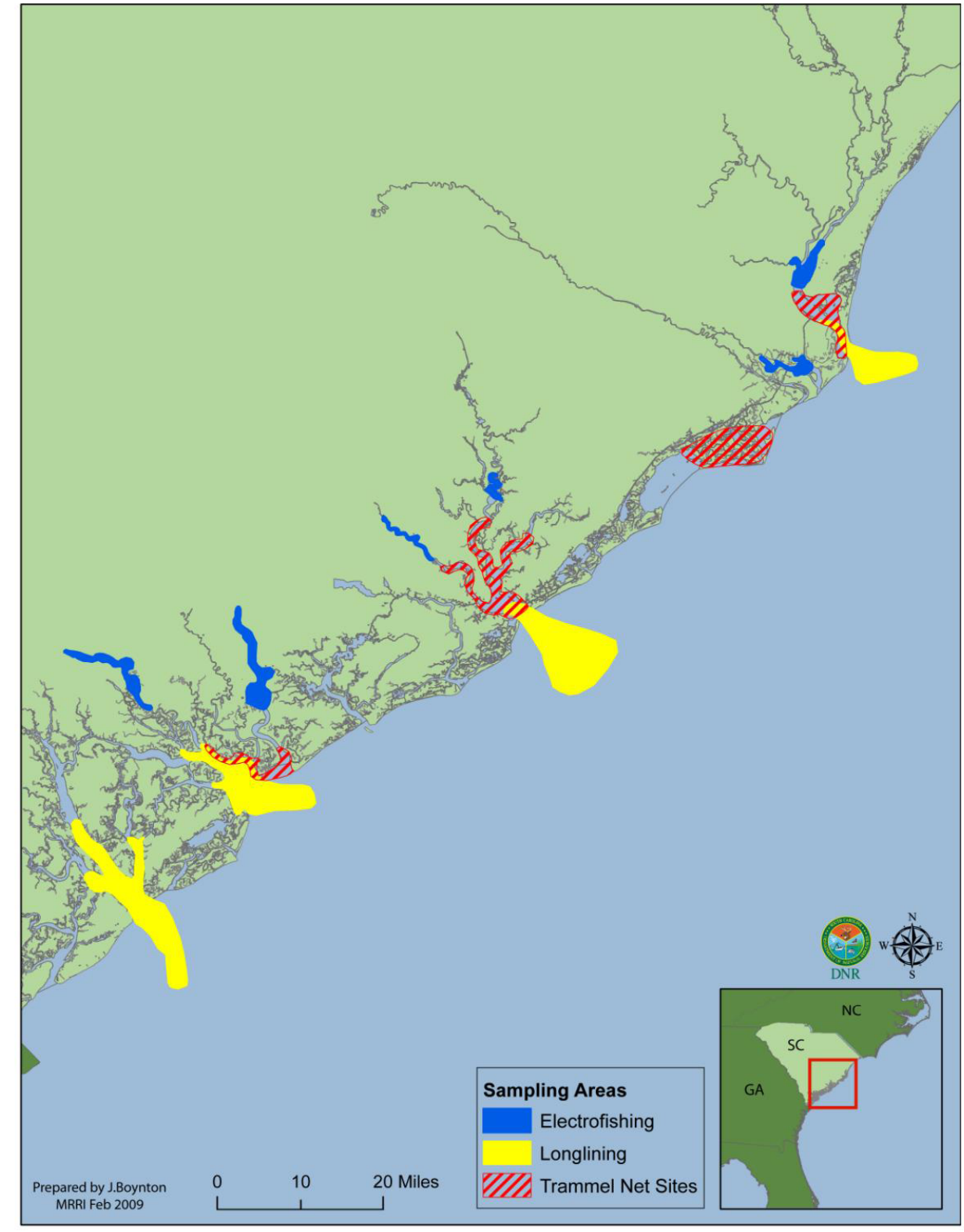


Figure 3. Fork lengths (mm) of sandbar sharks caught during the SC COASTSPAN longline survey from 1998-2009.

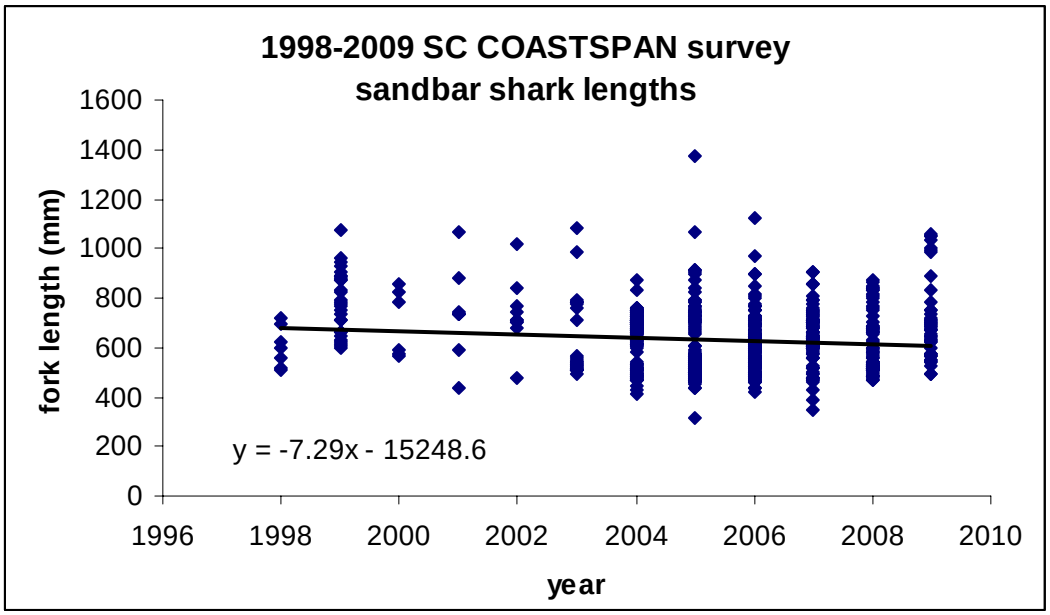


Figure 4a. SC COASTSPAN sandbar shark model diagnostic plots for the binomial component.

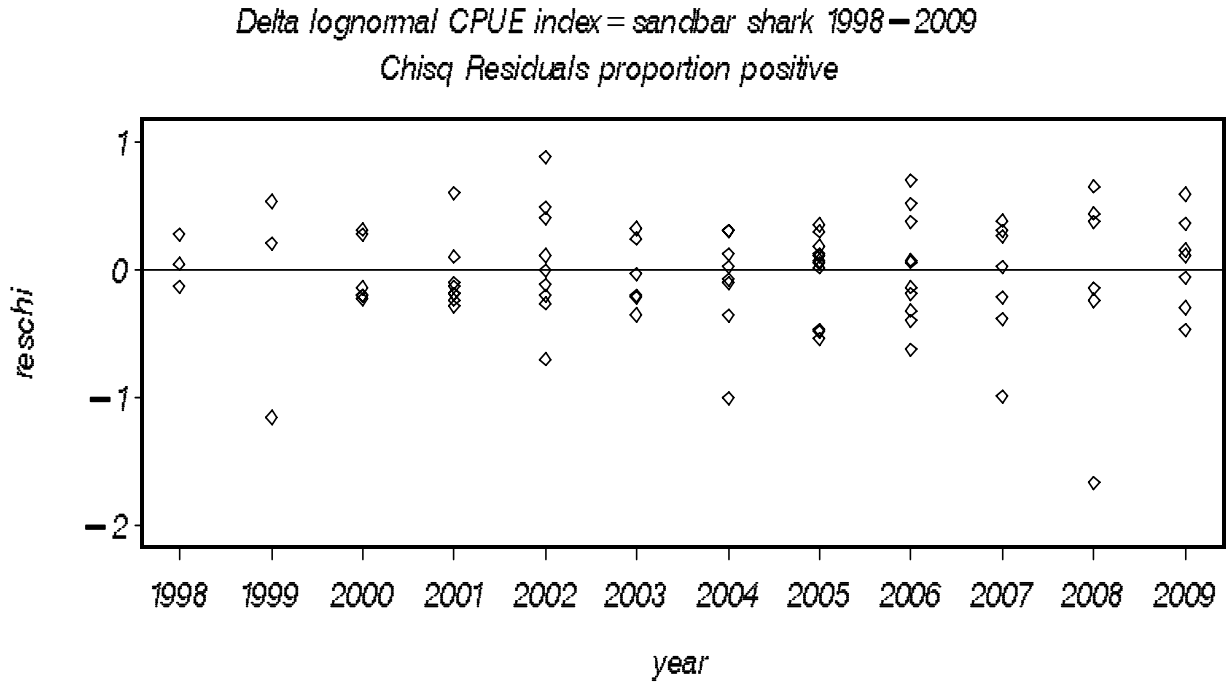
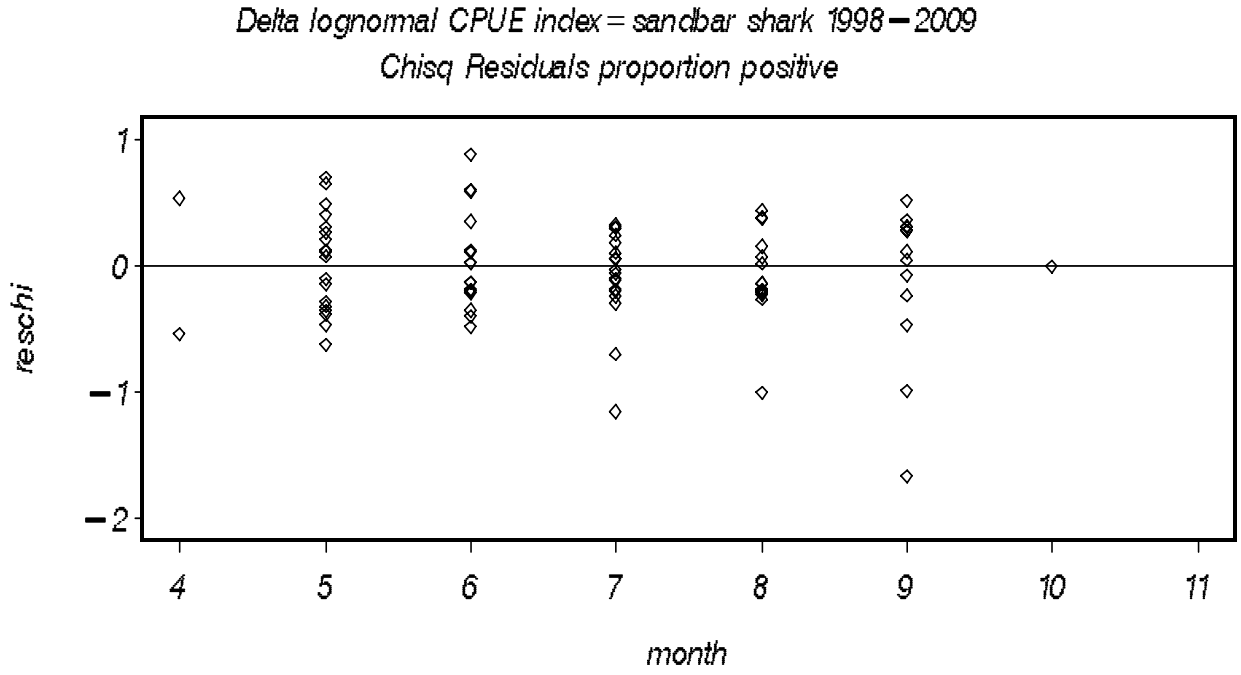


Figure 4a continued. SC COASTSPAN sandbar shark model diagnostic plots for the binomial component.



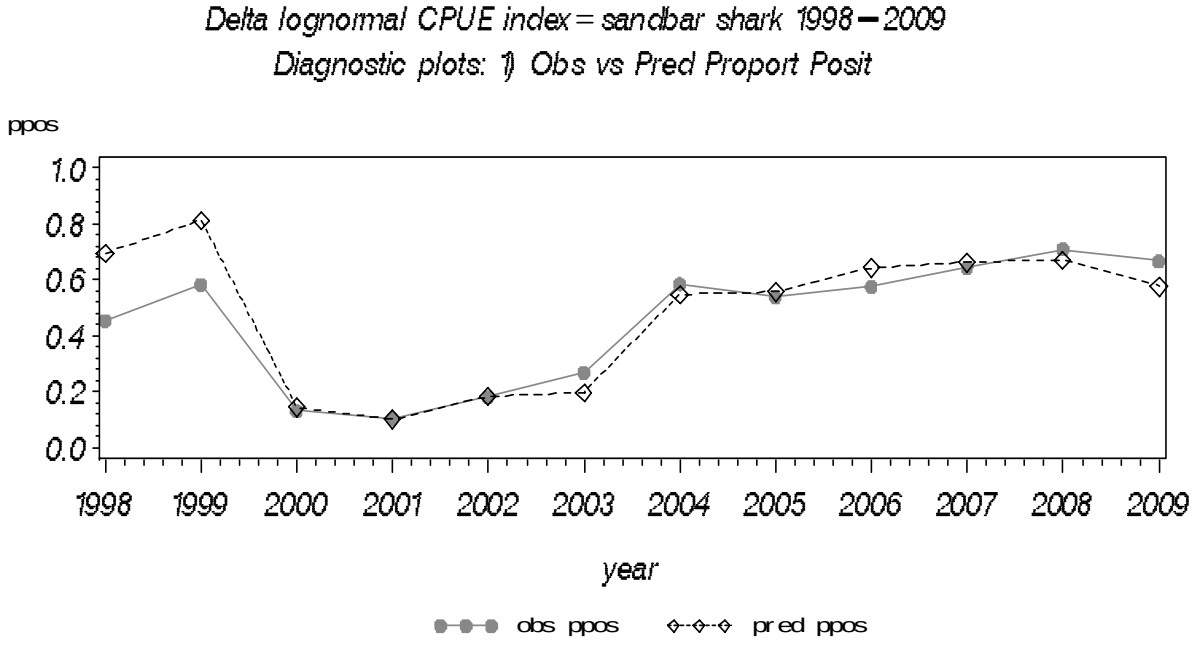
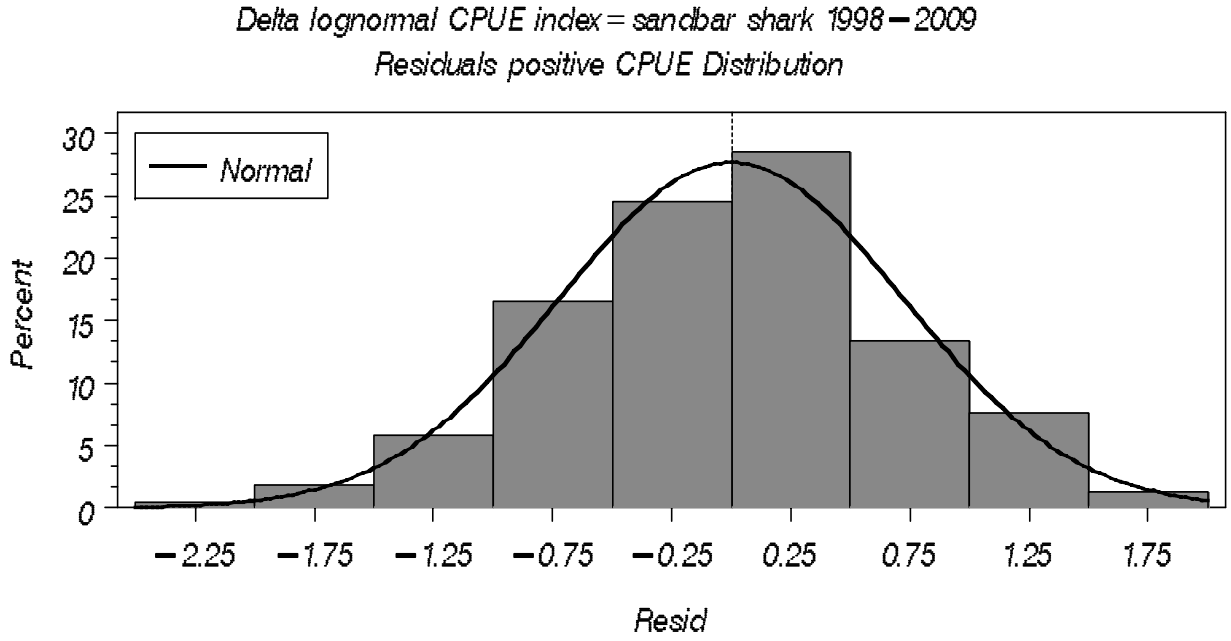


Figure 4b. SC COASTSPAN sandbar shark model diagnostic plots for the lognormal component.



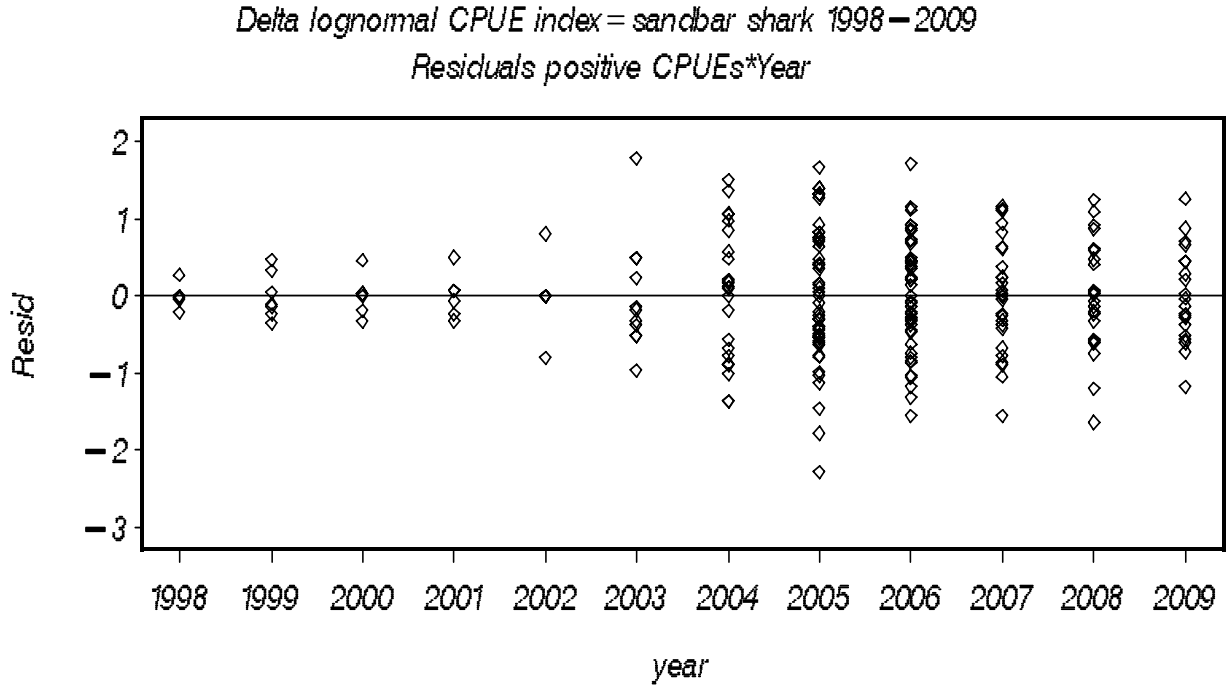
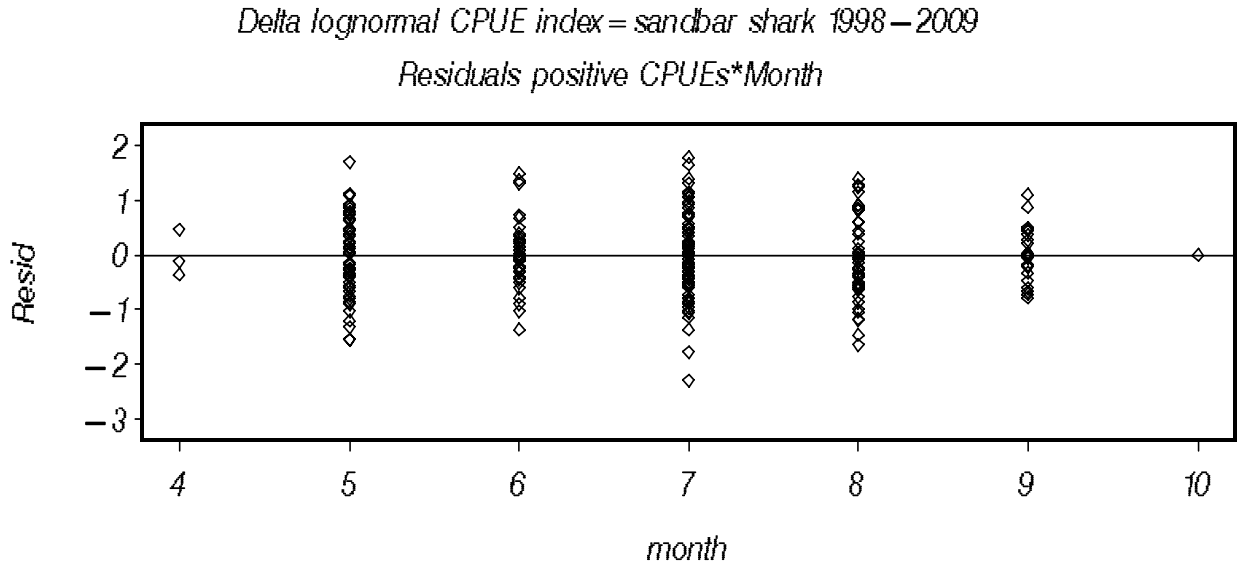


Figure 4b continued. SC COASTSPAN sandbar shark model diagnostic plots for the lognormal component.



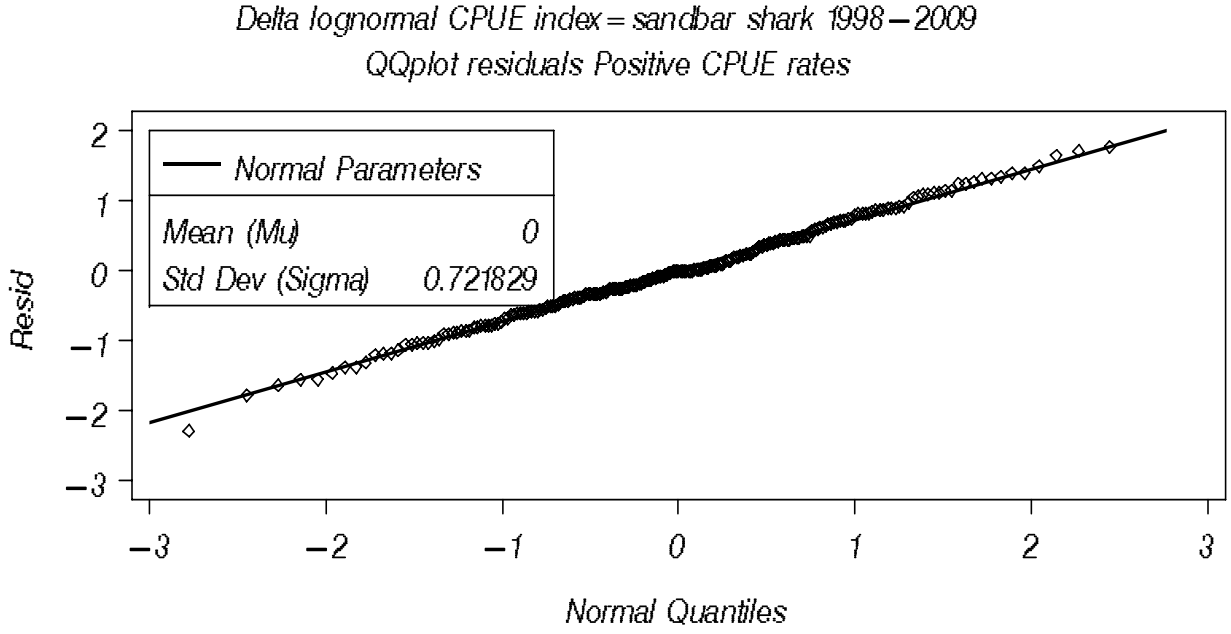


Figure 5. SC COASTSPAN sandbar shark nominal (obscpue2) and estimated (STDCPUE2) indices divided by the maximum values with 95% confidence limits (LCL2, UCL2).

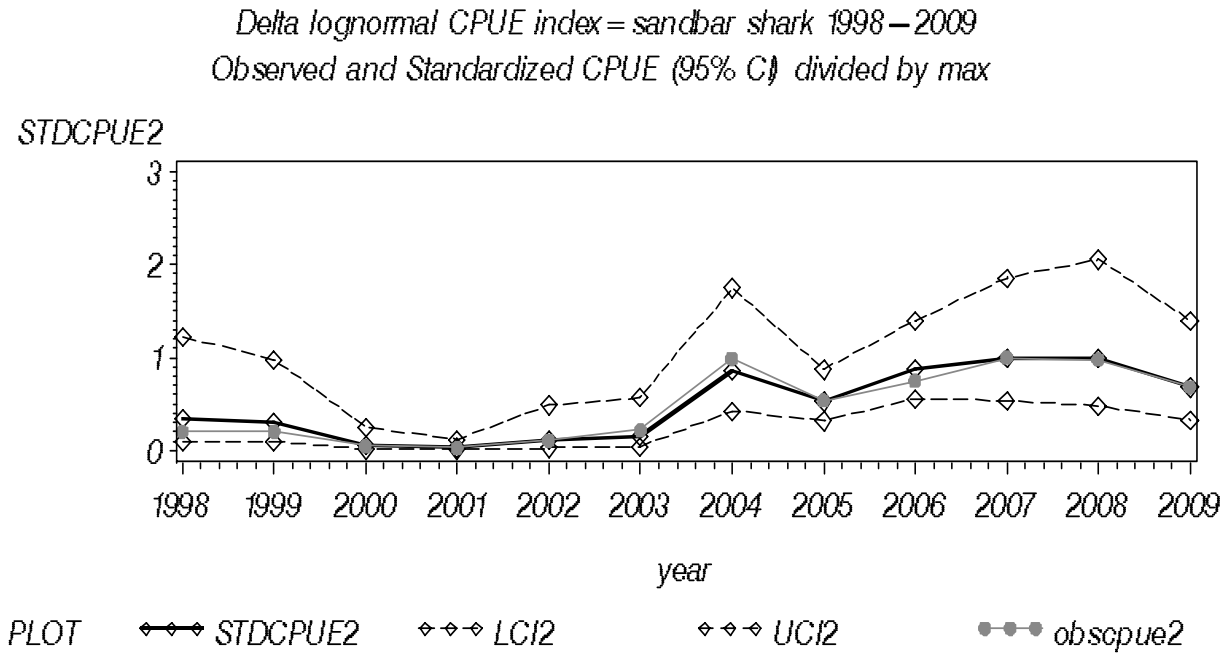


Figure 6. Fork lengths (mm) of sandbar sharks caught during the 1998-2006 SCDNR red drum longline survey.

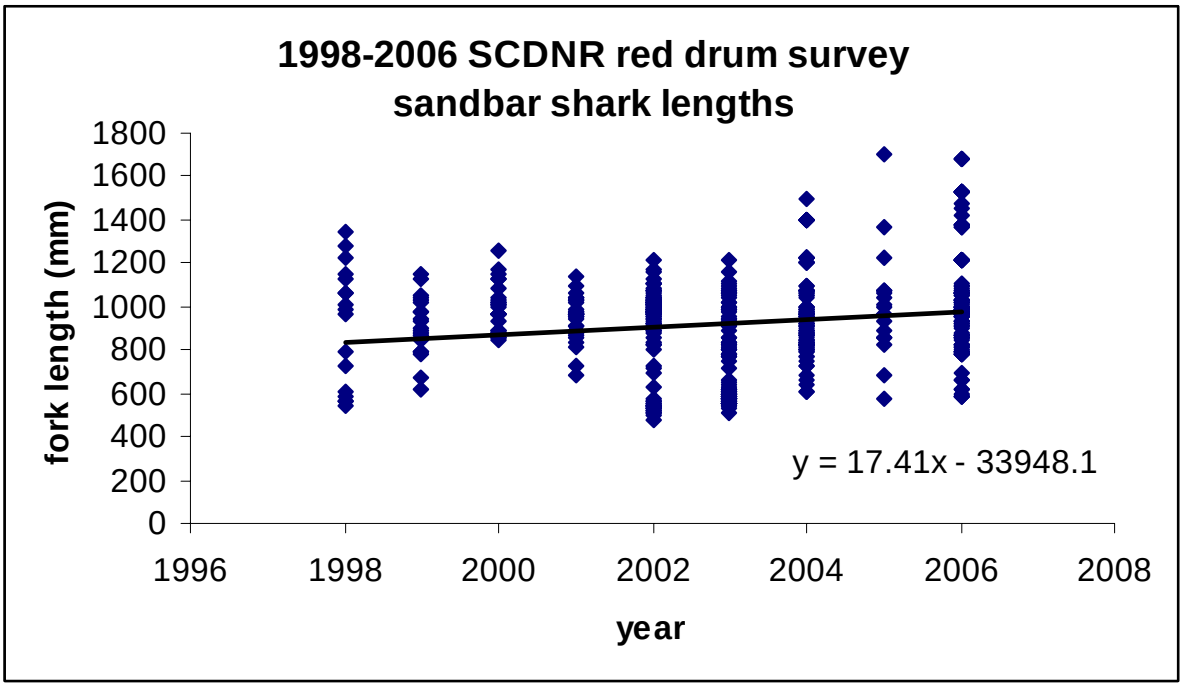
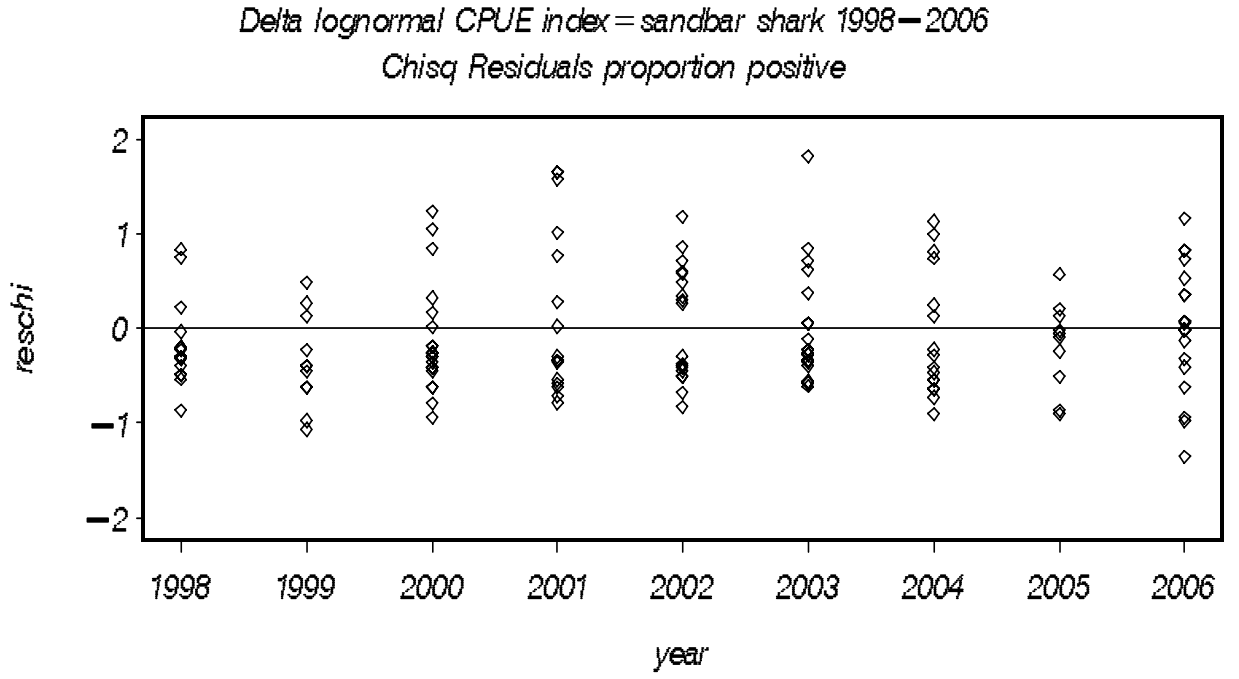


Figure 7a. 1998-2006 SCDNR red drum survey sandbar shark model diagnostic plots for the binomial component.



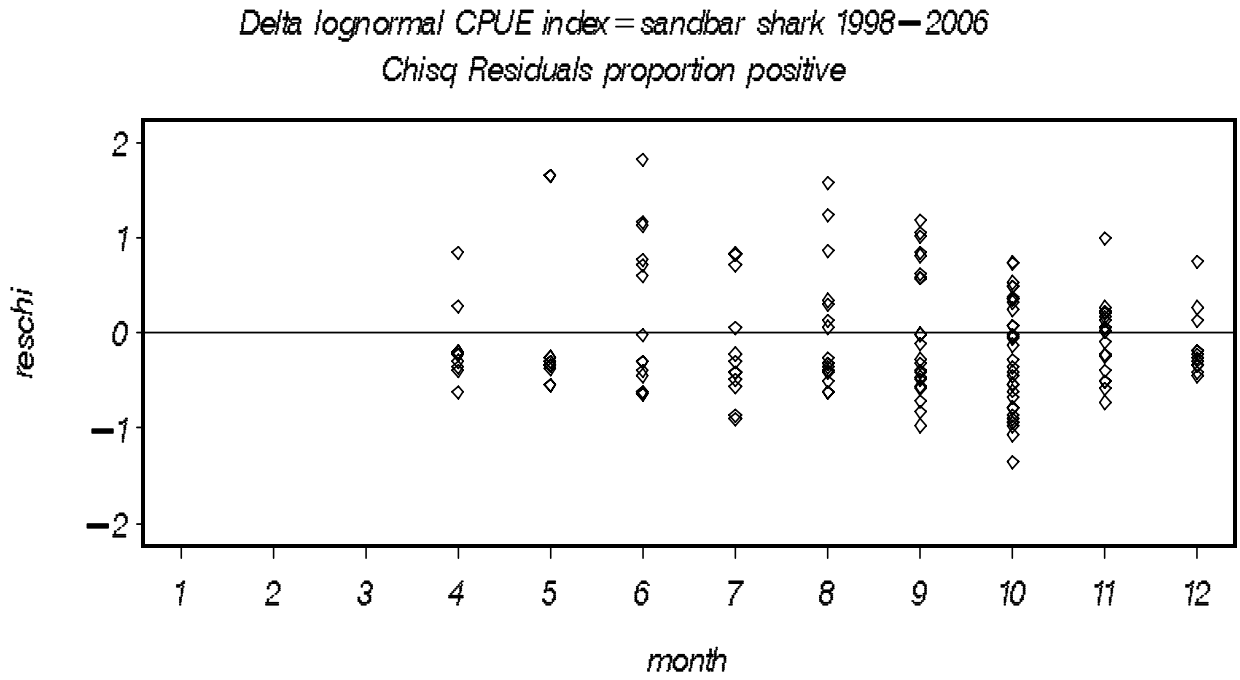


Figure 7a continued. 1998-2006 SCDNR red drum survey sandbar shark model diagnostic plots for the binomial component.

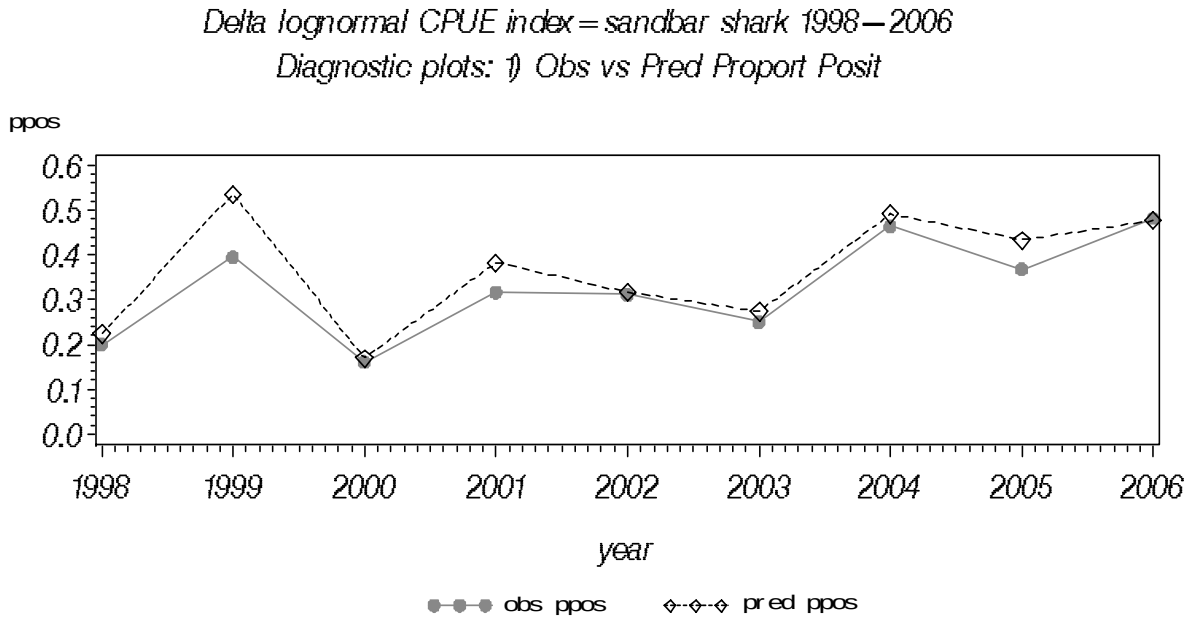


Figure 7b. 1998-2006 SCDNR red drum survey sandbar shark model diagnostic plots for the lognormal component.

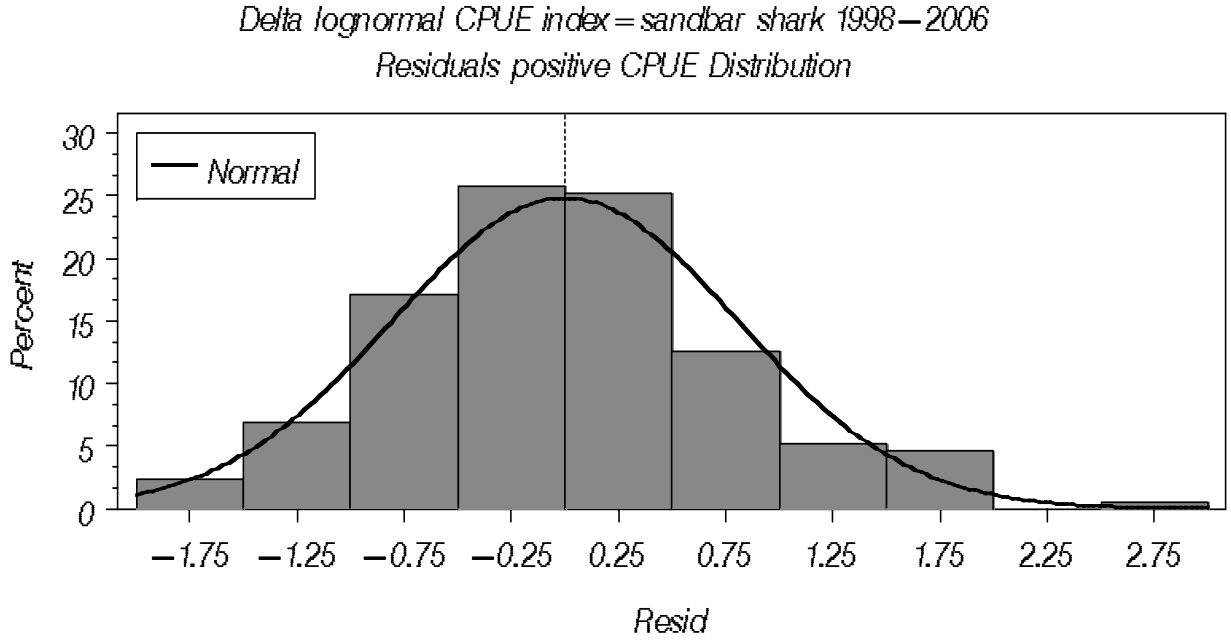
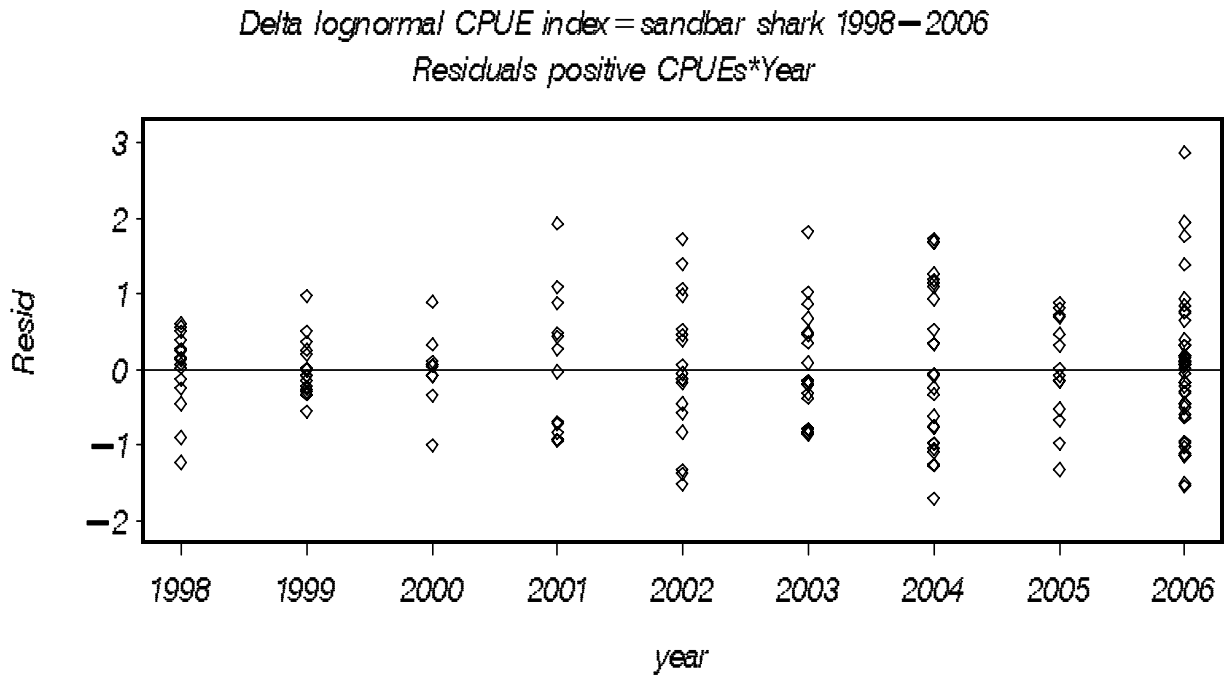


Figure 7b continued. 1998-2006 SCDNR red drum survey sandbar shark model diagnostic plots for the lognormal component.



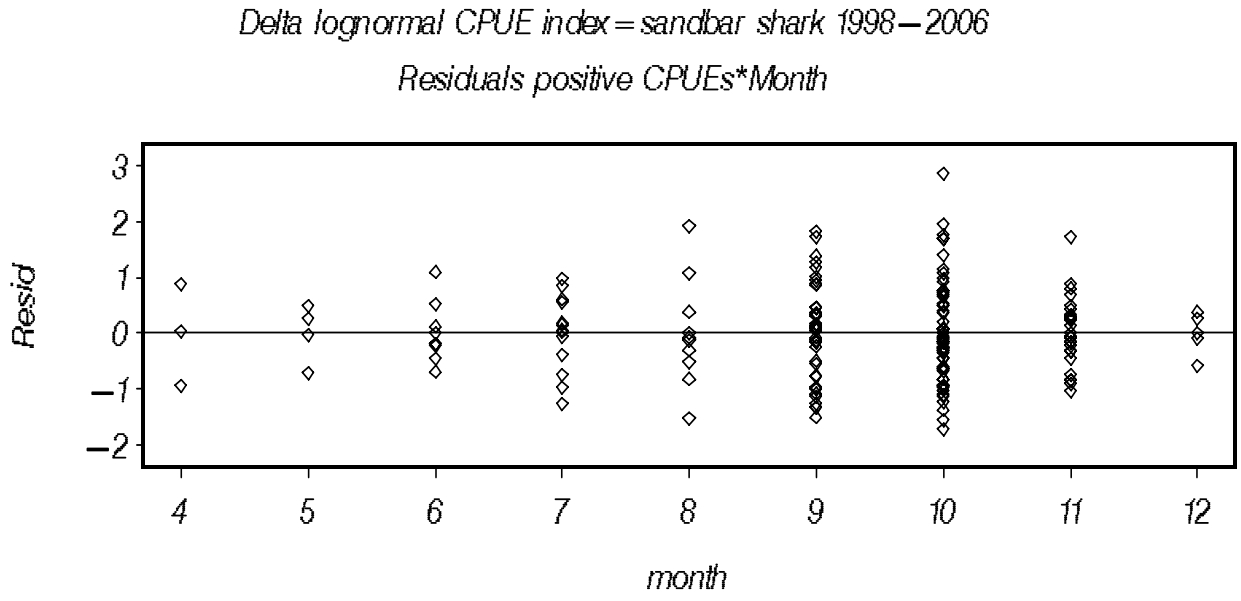


Figure 7b continued. 1998-2006 SCDNR red drum survey sandbar shark model diagnostic plots for the lognormal component.

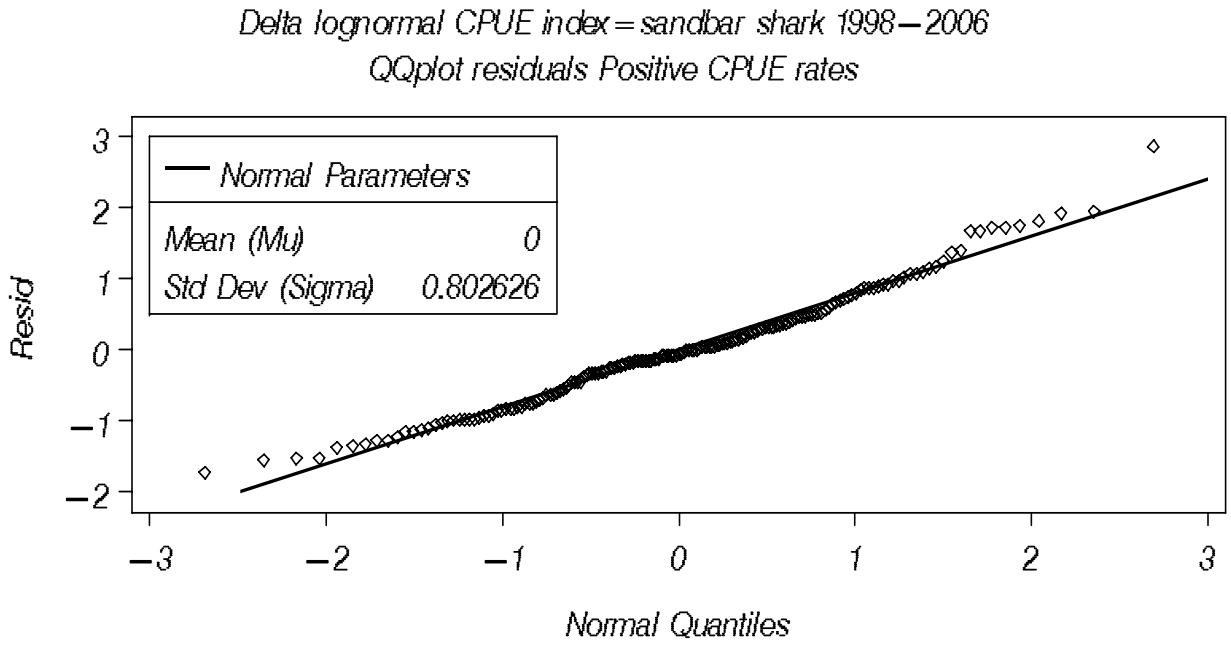


Figure 8. SCDNR red drum survey sandbar shark nominal (obscpue2) and estimated (STDCPUE2) indices divided by the maximum values with 95% confidence limits (LCL2, UCL2).

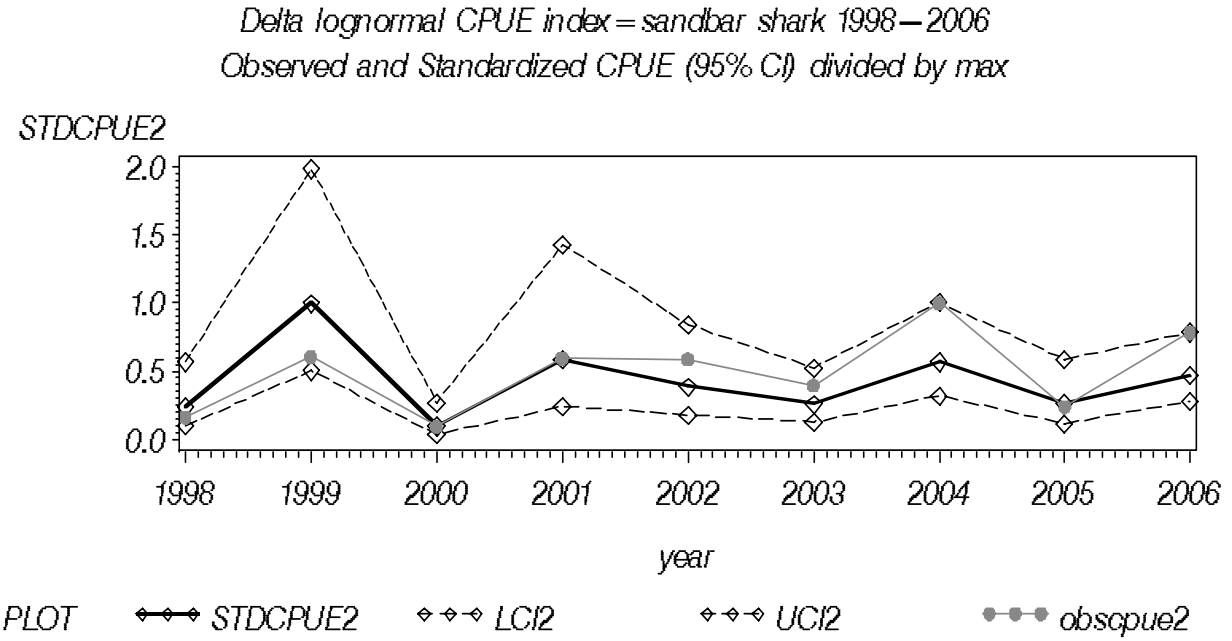


Figure 9. Fork lengths (mm) of blacknose sharks caught during the 1998-2006 SCDNR red drum longline survey.

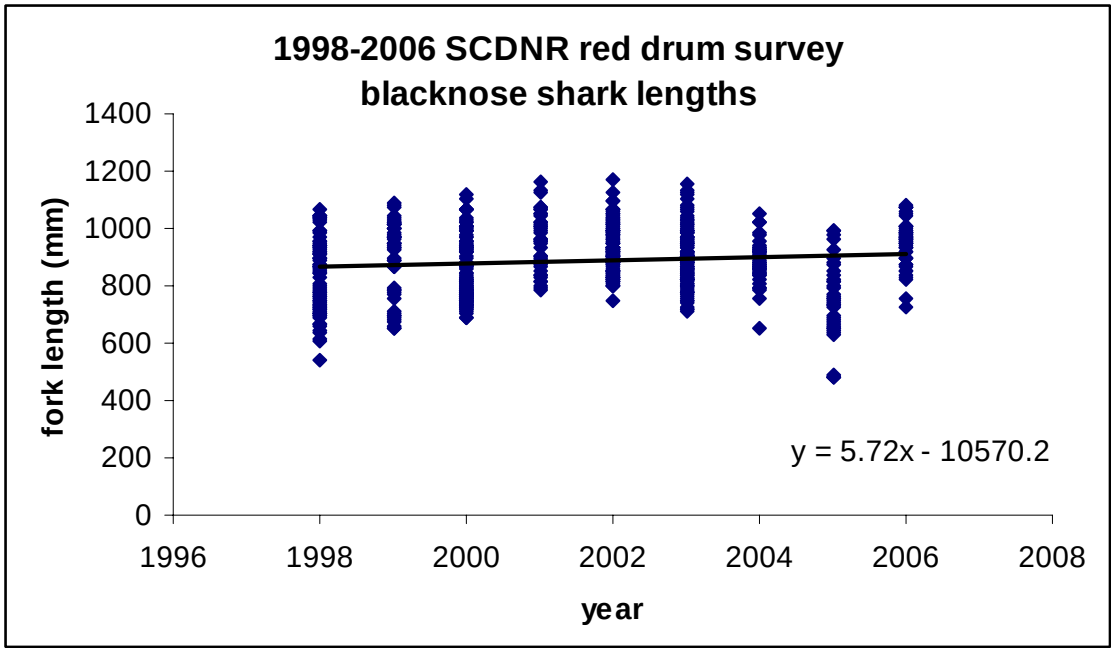


Figure 10a. 1998-2006 SCDNR red drum survey blacknose shark model diagnostic plots for the binomial component.

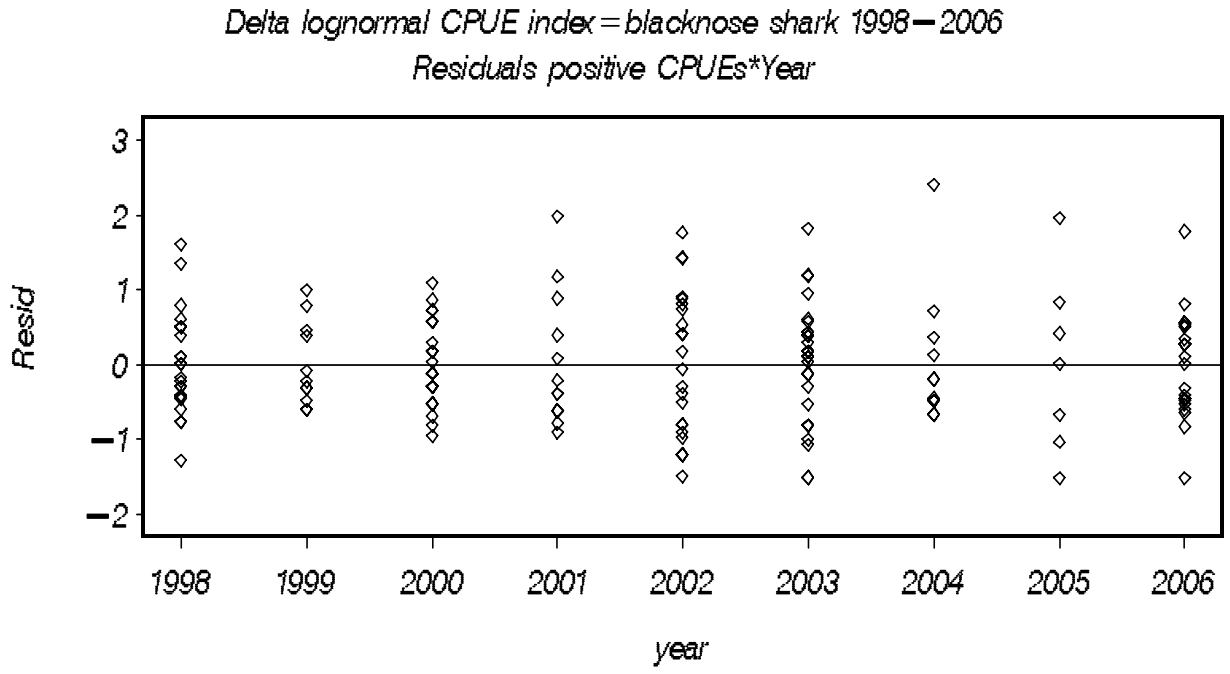
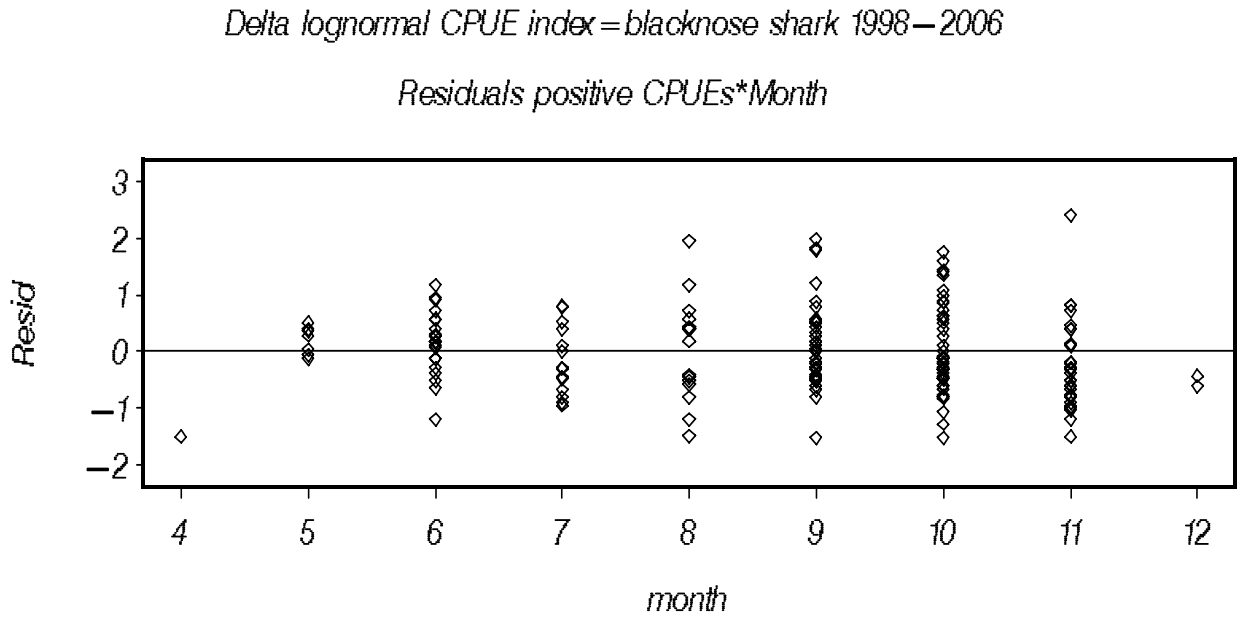


Figure 10a continued. 1998-2006 SCDNR red drum survey blacknose shark model diagnostic plots for the binomial component.



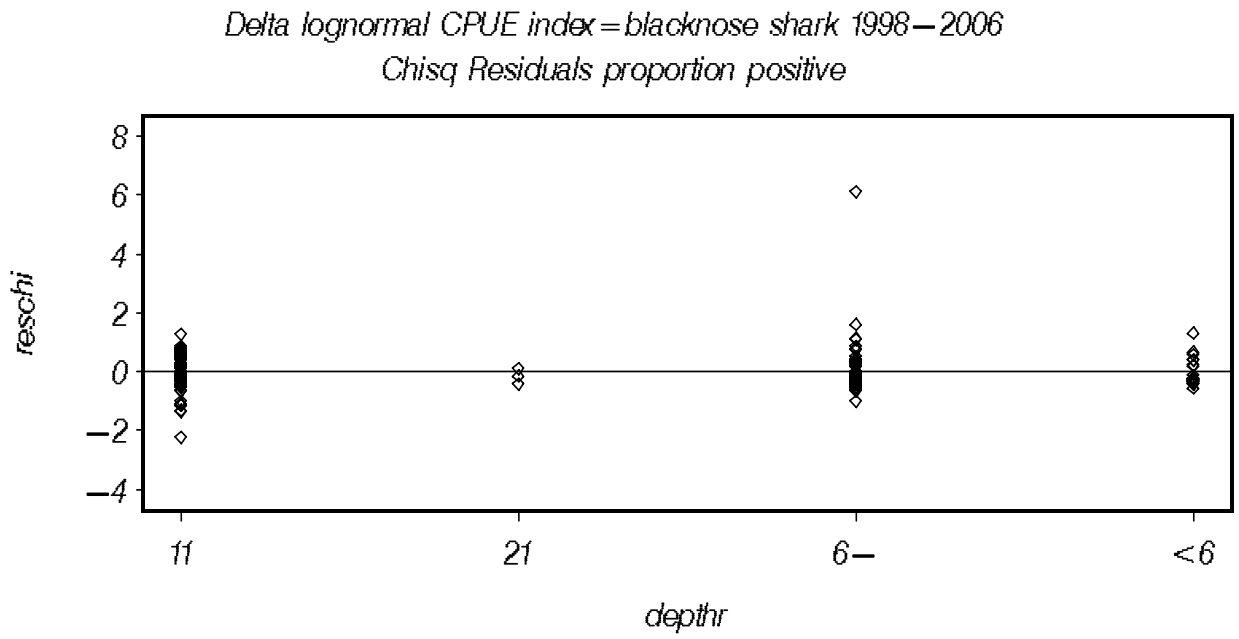


Figure 10a continued. 1998-2006 SCDNR red drum survey blacknose shark model diagnostic plots for the binomial component.

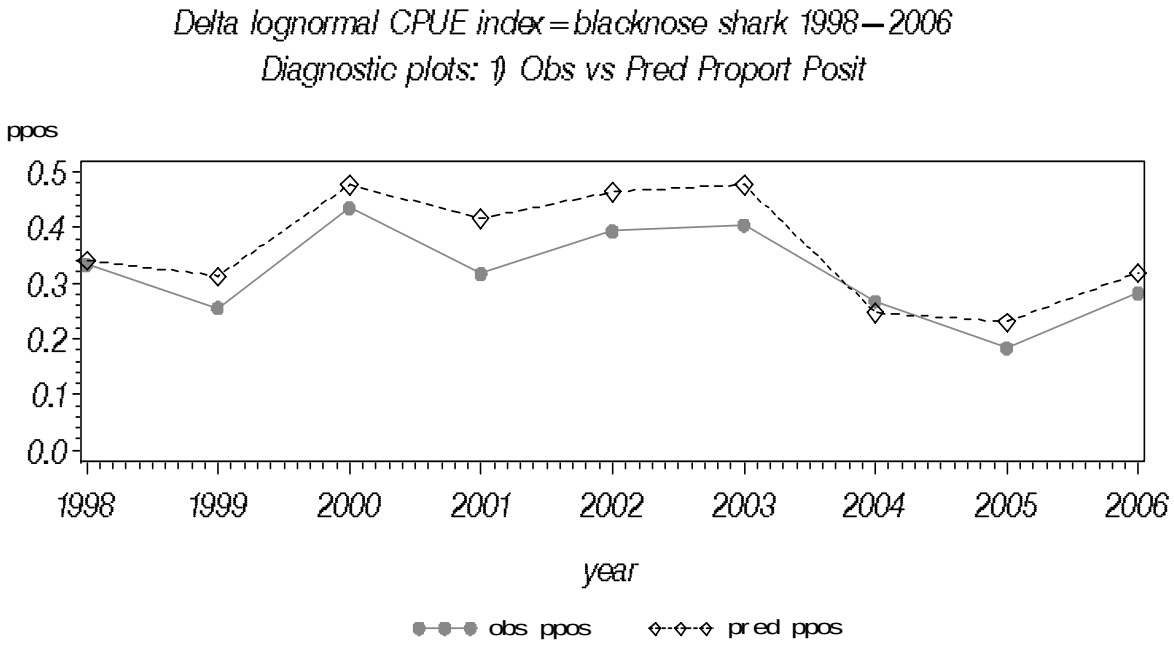


Figure 10b. 1998-2006 SCDNR red drum survey blacknose shark model diagnostic plots for the lognormal component.

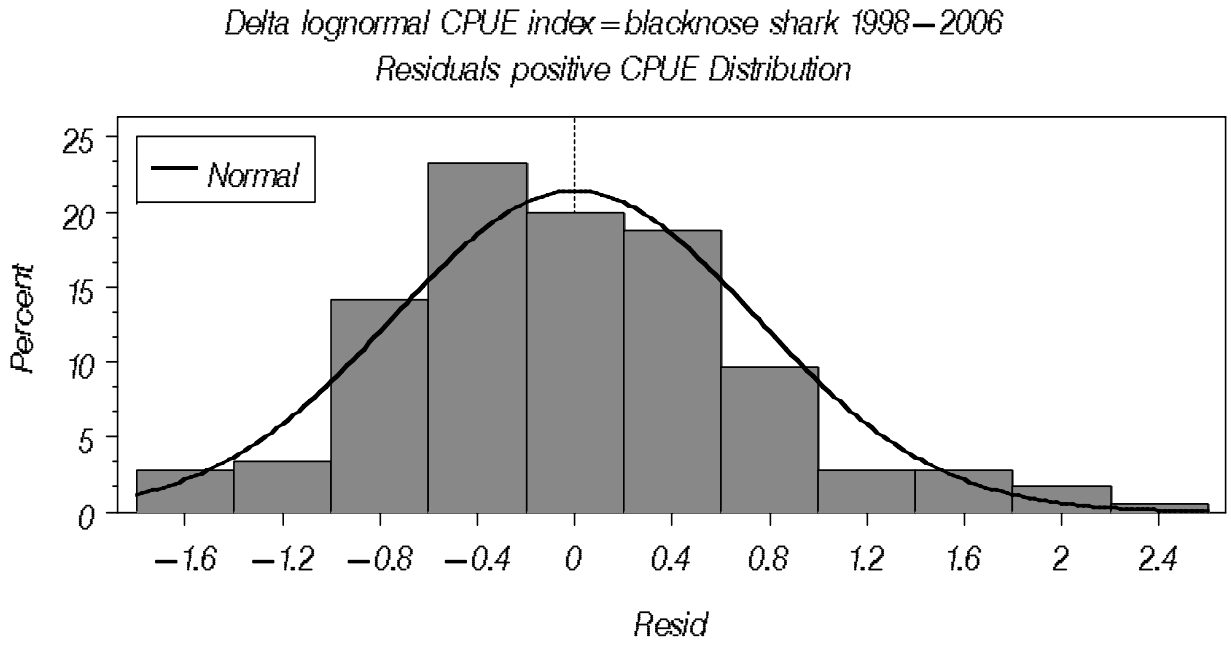
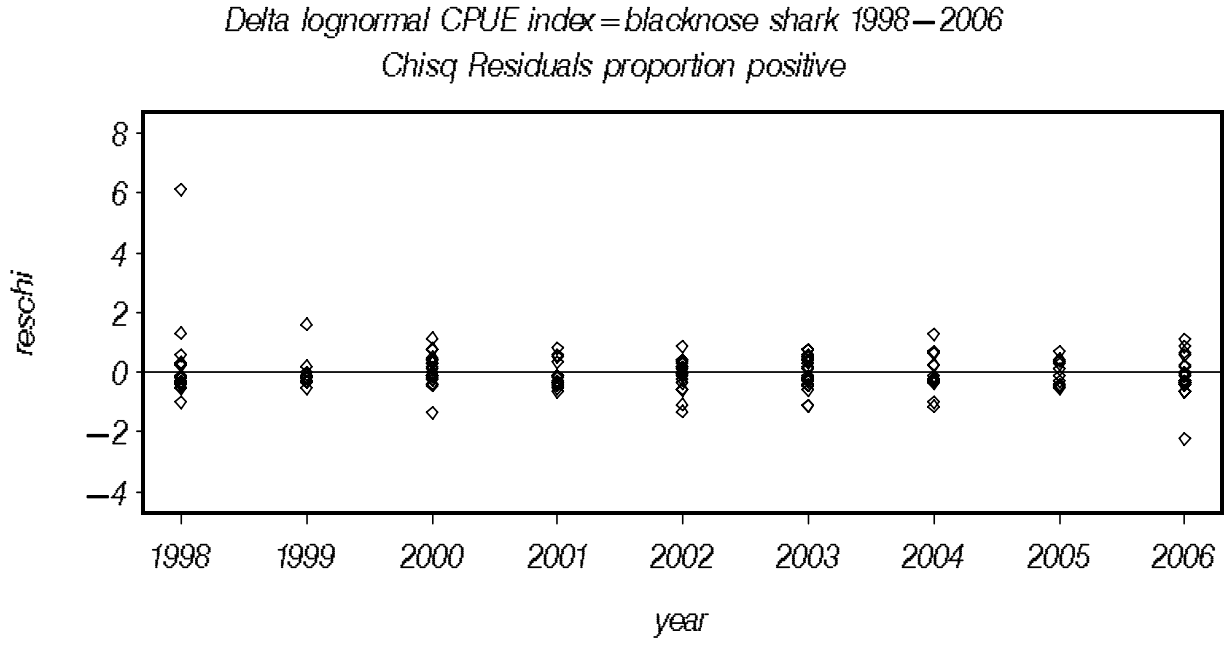


Figure 10b continued. 1998-2006 SCDNR red drum survey blacknose shark model diagnostic plots for the lognormal component.



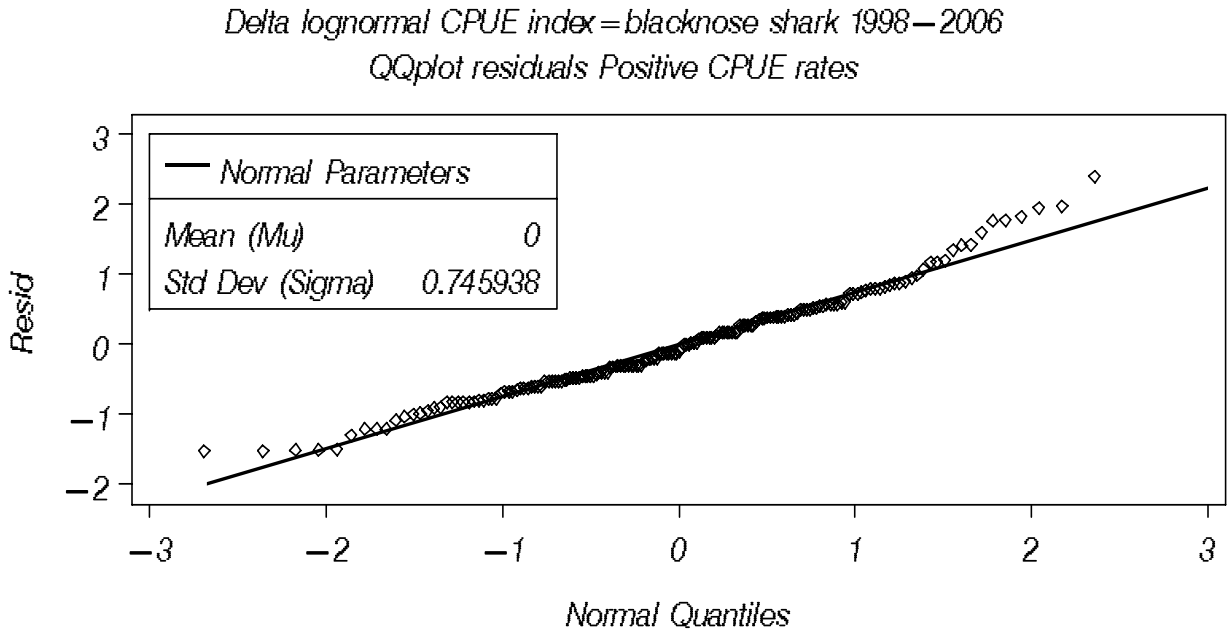


Figure 11. 1998-2006 SCDNR red drum survey blacknose shark nominal (obscpue2) and estimated (STDCPUE2) indices divided by the maximum values with 95% confidence limits (LCL2, UCL2).

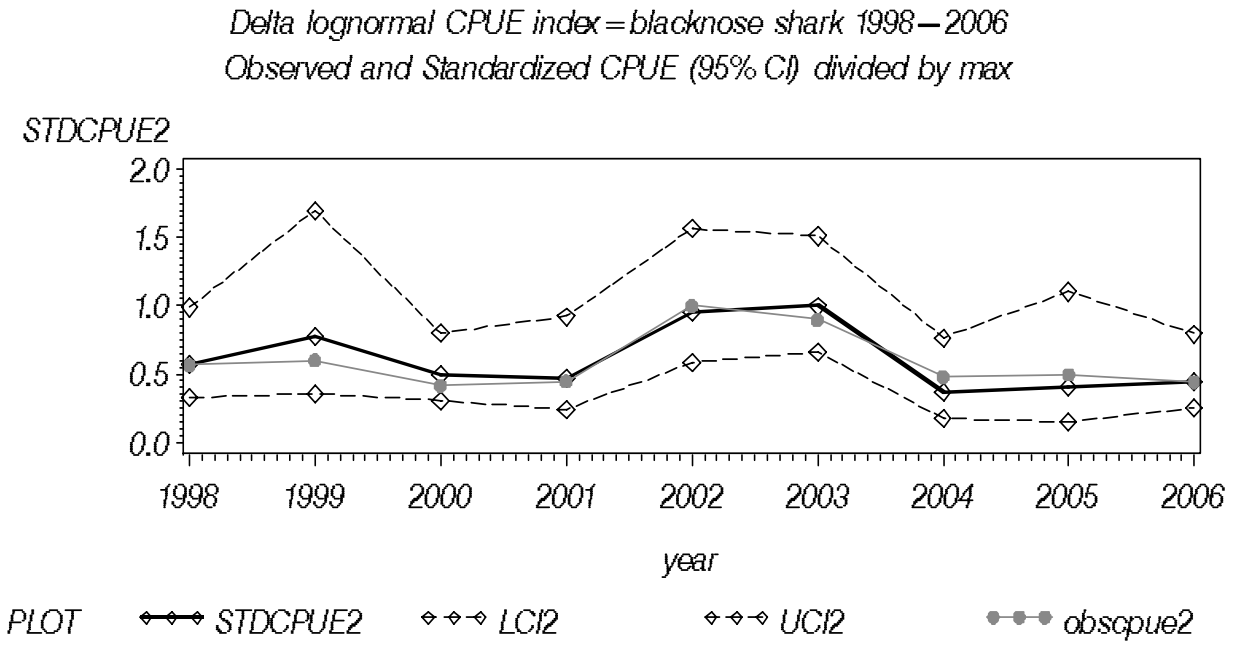


Figure 12. Fork lengths (mm) of sandbar sharks caught during the 2007-2009 SCDNR red drum longline survey.

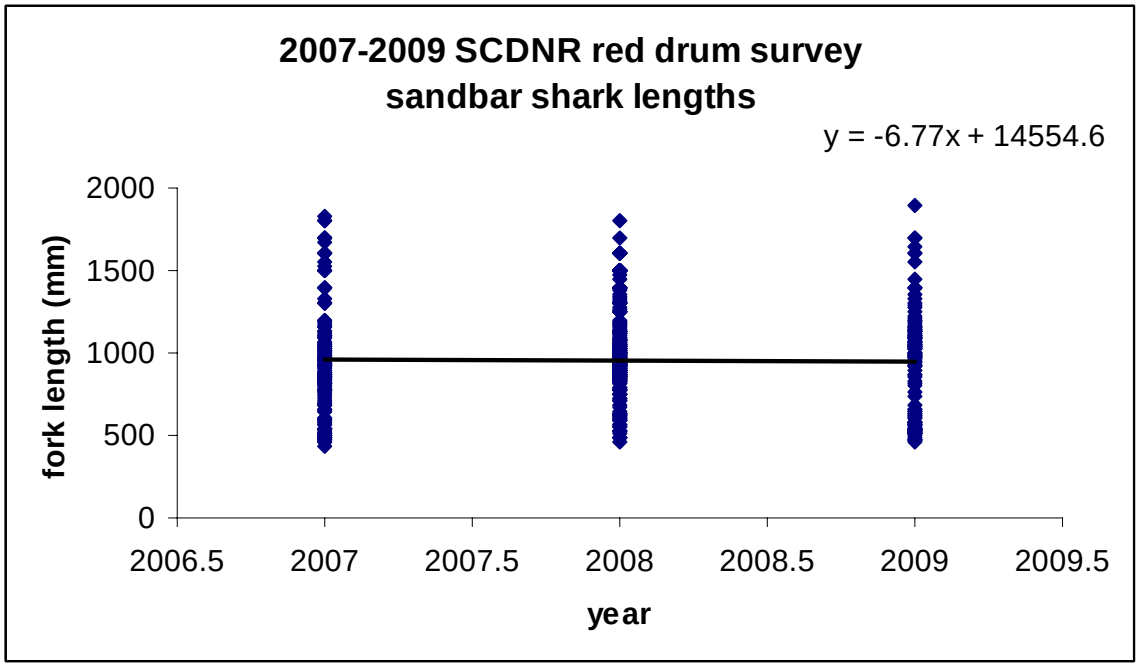
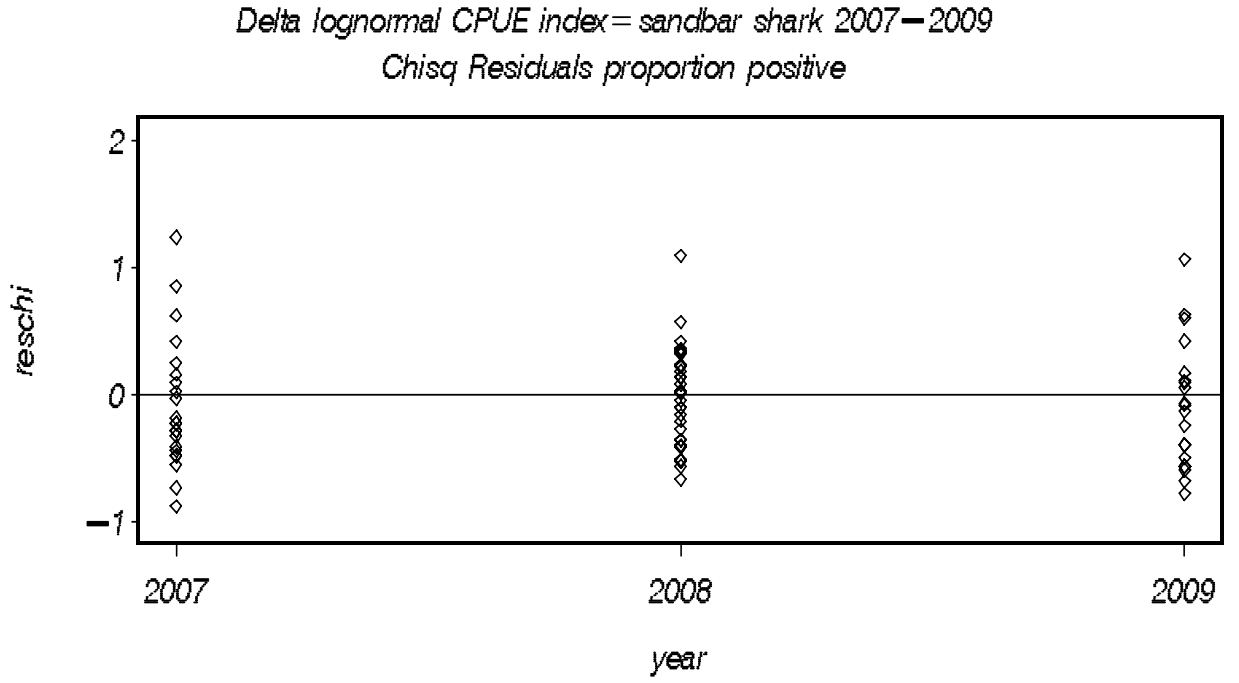


Figure 13a. 2007-2009 SCDNR red drum survey sandbar shark model diagnostic plots for the binomial component.



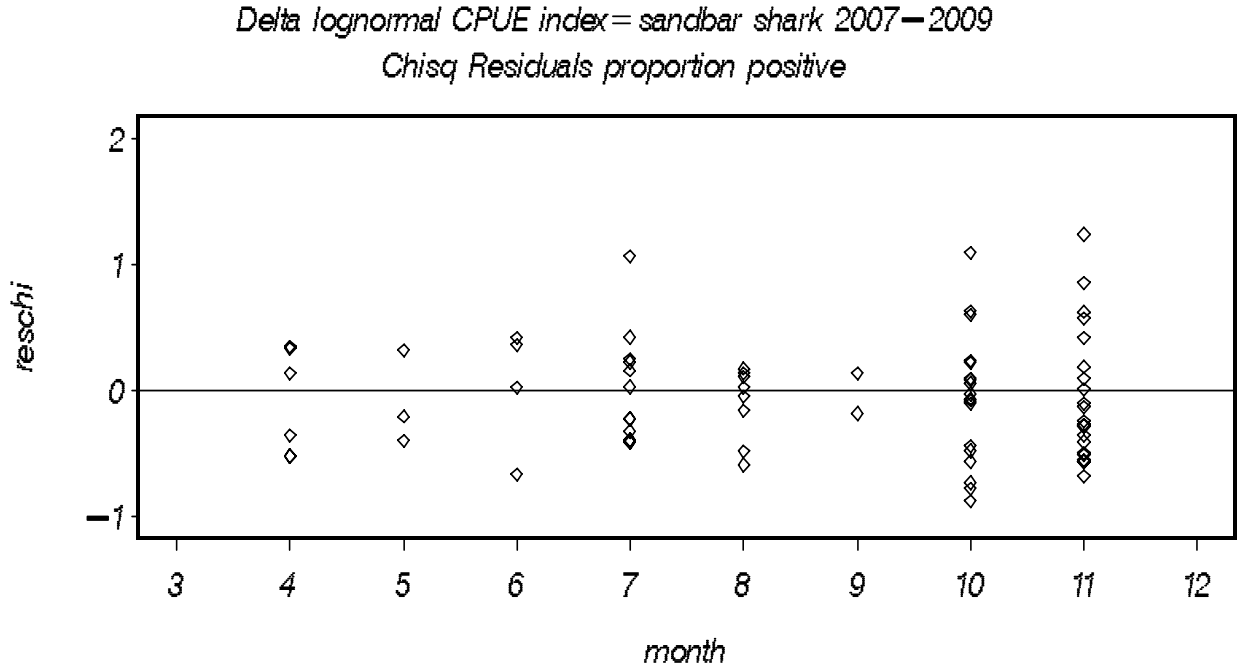


Figure 13a continued. 2007-2009 SCDNR red drum survey sandbar shark model diagnostic plots for the binomial component.

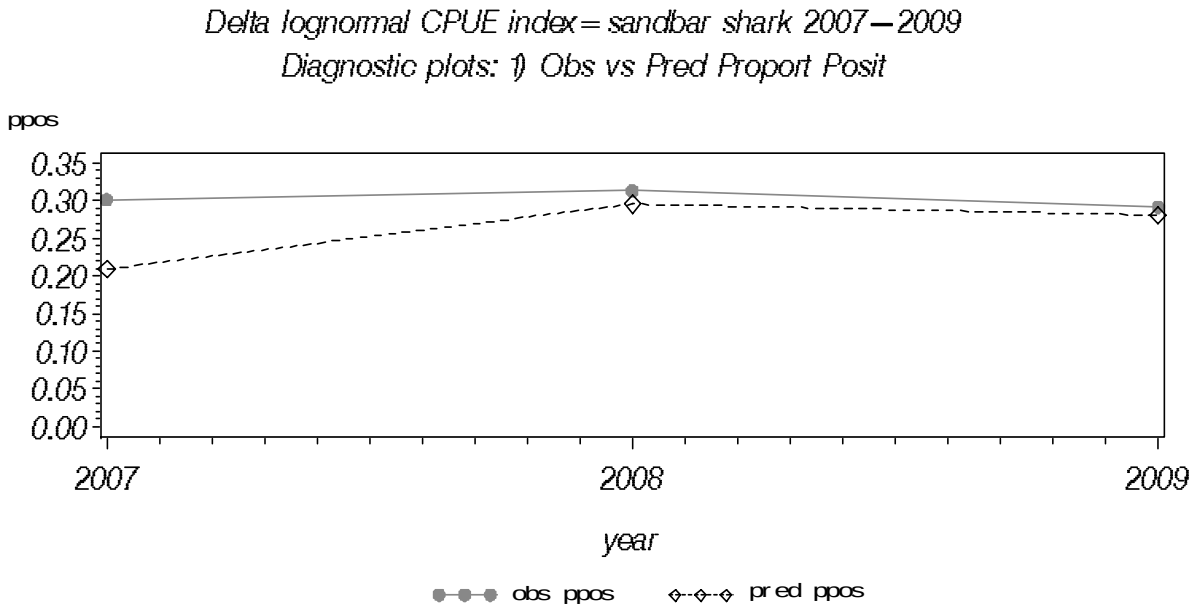


Figure 13b. 2007-2009 SCDNR red drum survey sandbar shark model diagnostic plots for the lognormal component.

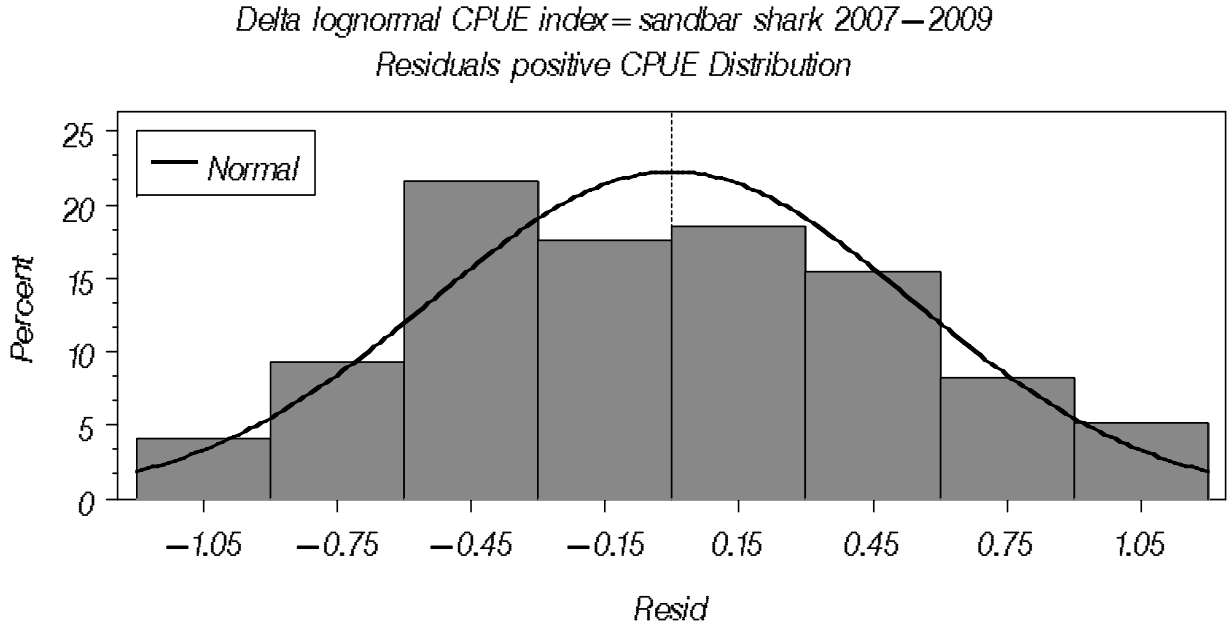
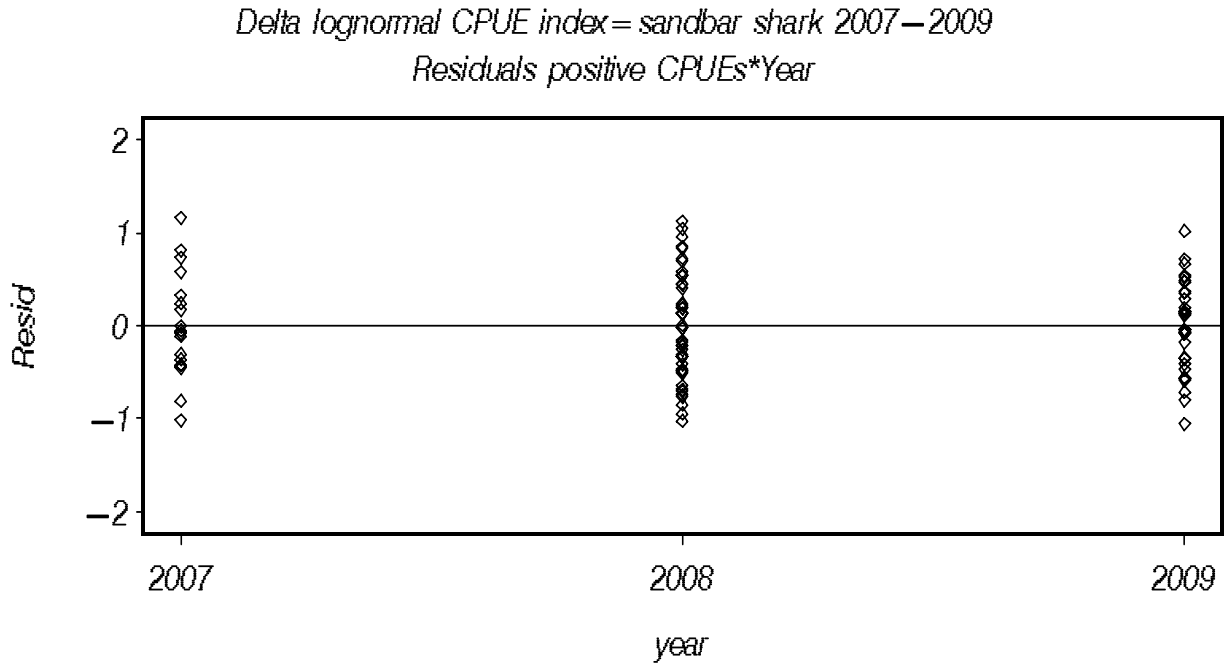


Figure 13b continued. 2007-2009 SCDNR red drum survey sandbar shark model diagnostic plots for the lognormal component.



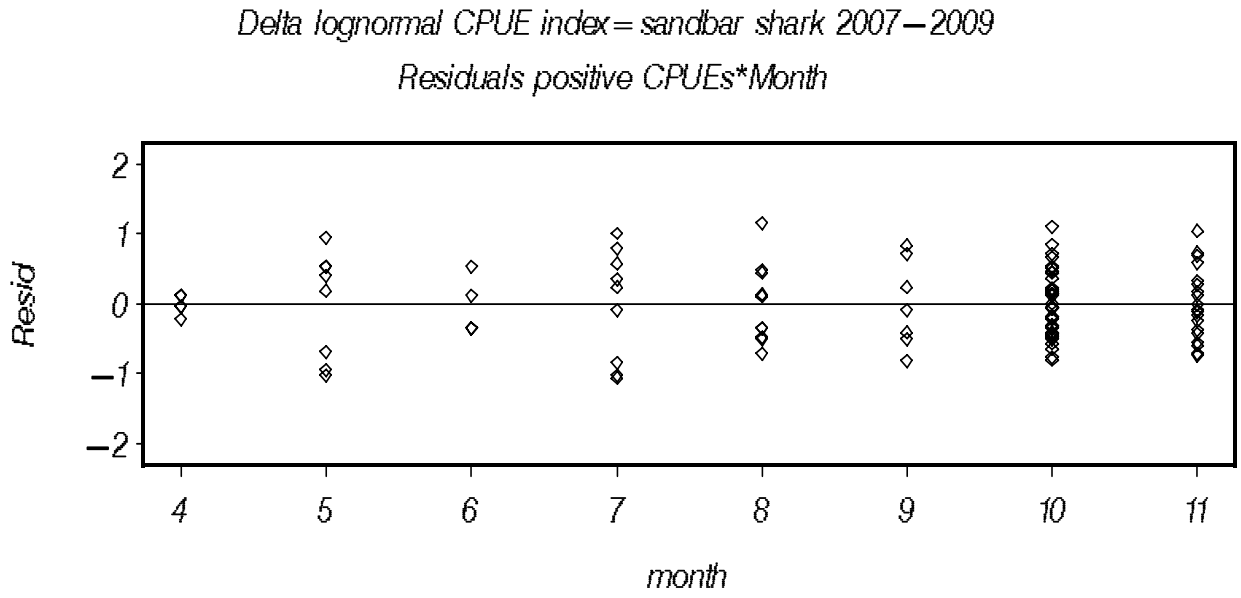


Figure 13b continued. 2007-2009 SCDNR red drum survey sandbar shark model diagnostic plots for the lognormal component.

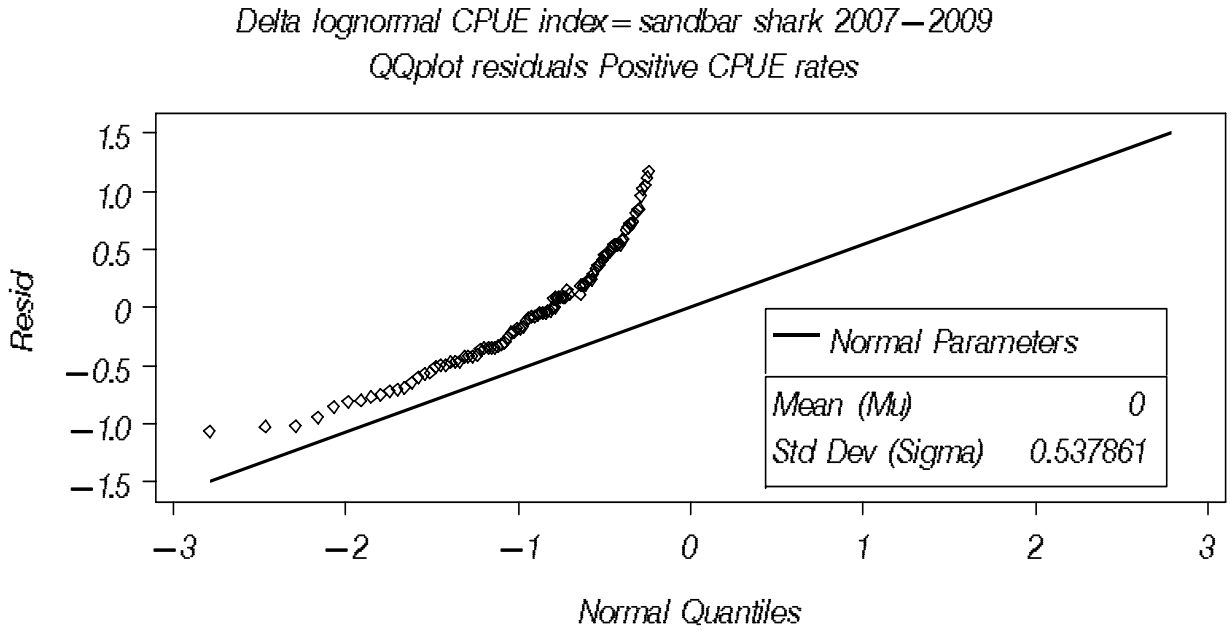


Figure 14. 2007-2009 SCDNR red drum survey sandbar shark nominal (obscpue2) and estimated (STDCPUE2) indices divided by the maximum values with 95% confidence limits (LCL2, UCL2).

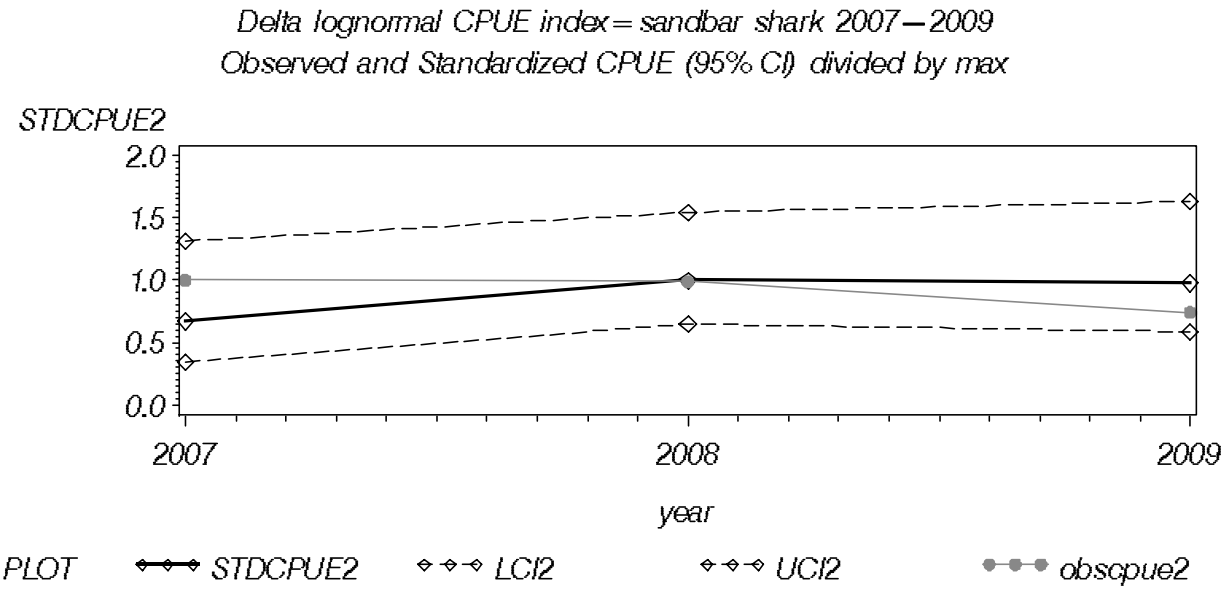


Figure 15. Fork lengths (mm) of blacknose sharks caught during the 2007-2009 SCDNR red drum longline survey.

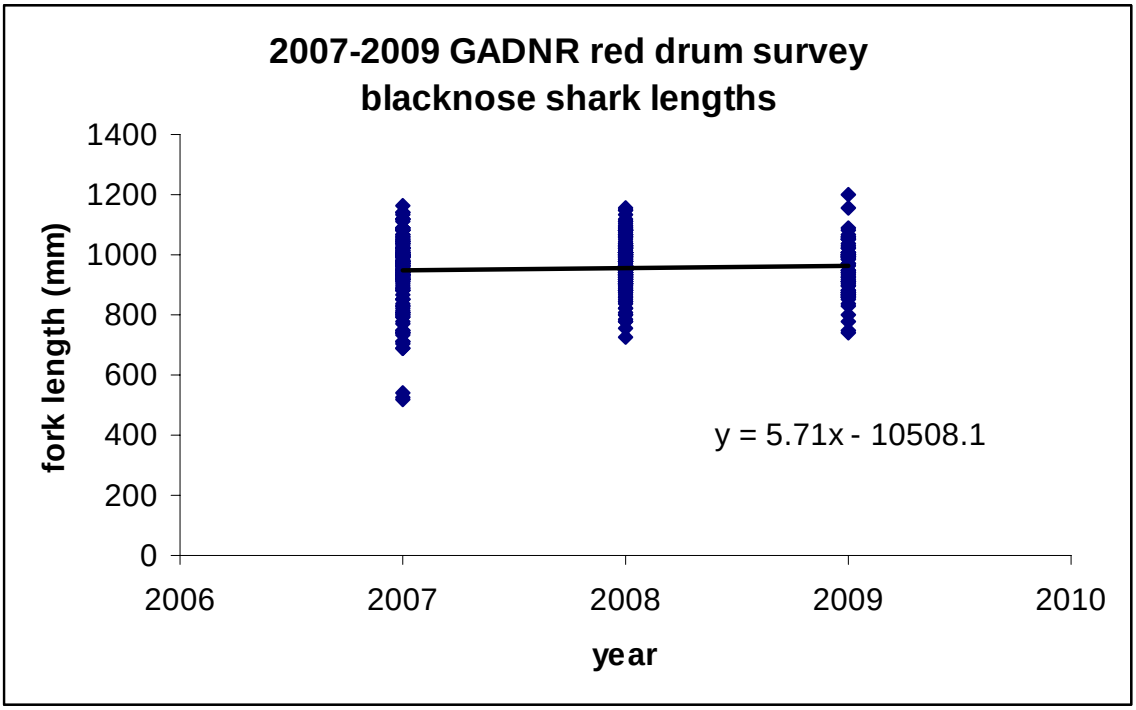


Figure 16a. 2007-2009 SCDNR red drum survey blacknose shark model diagnostic plots for the binomial component.

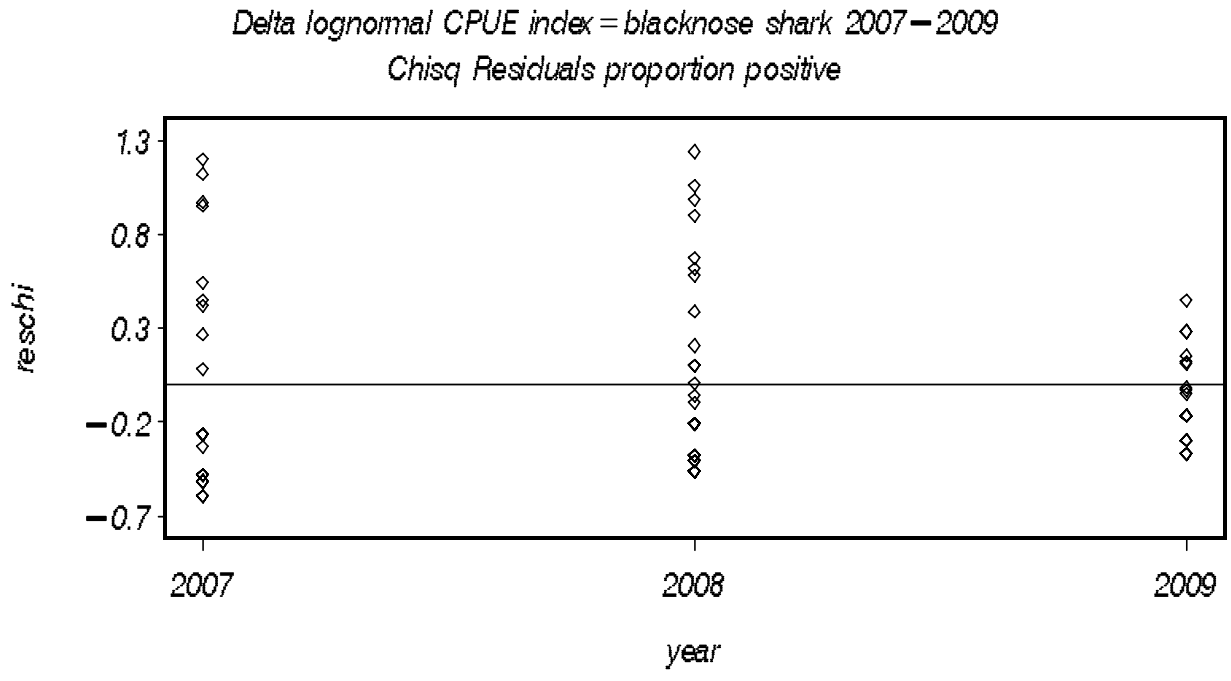


Figure 16a continued. 2007-2009 SCDNR red drum survey blacknose shark model diagnostic plots for the binomial component.

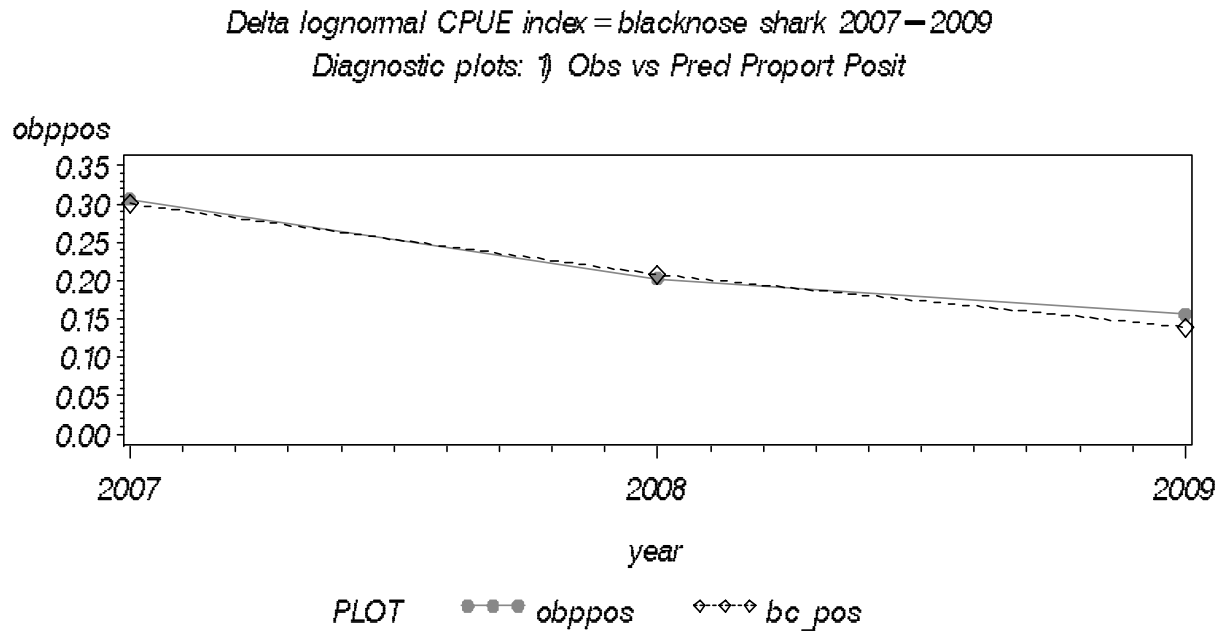


Figure 16b. 2007-2009 SCDNR red drum survey blacknose shark model diagnostic plots for the lognormal component.

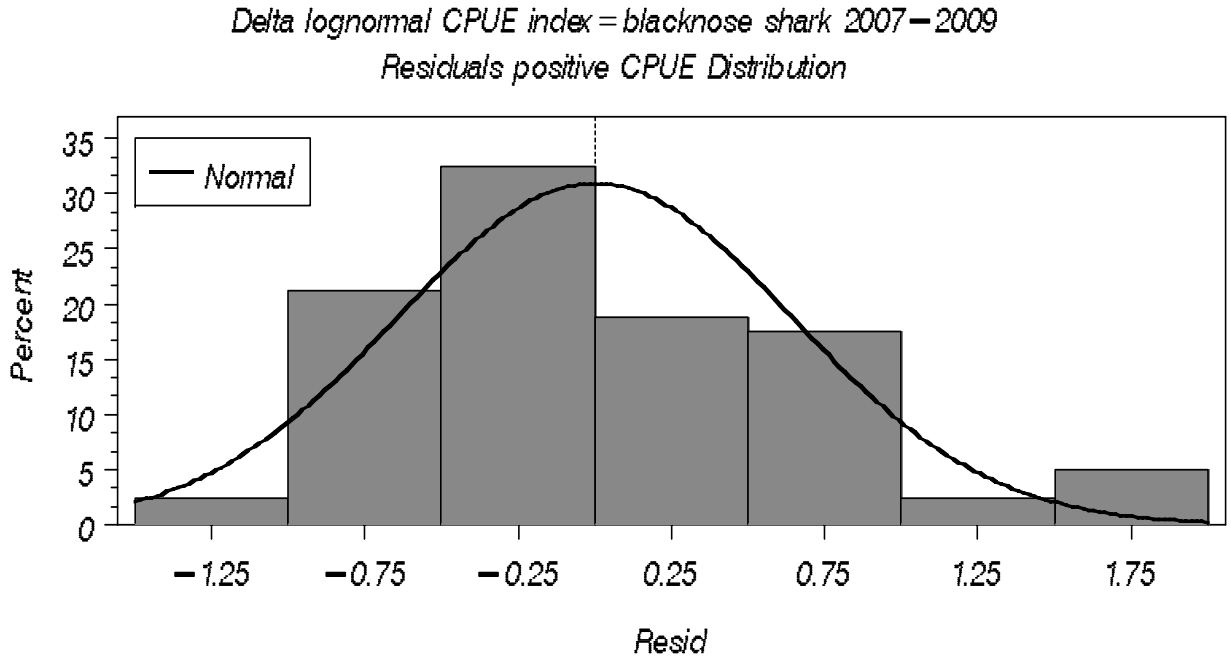
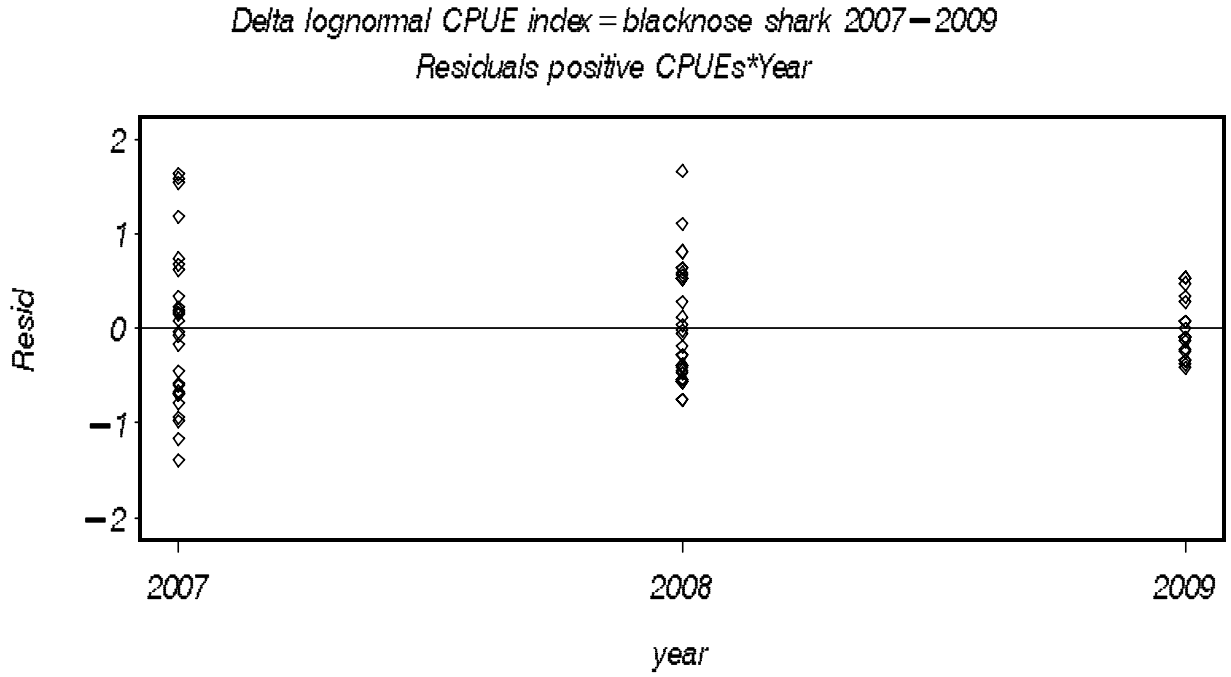


Figure 16b continued. 2007-2009 SCDNR red drum survey blacknose shark model diagnostic plots for the lognormal component.



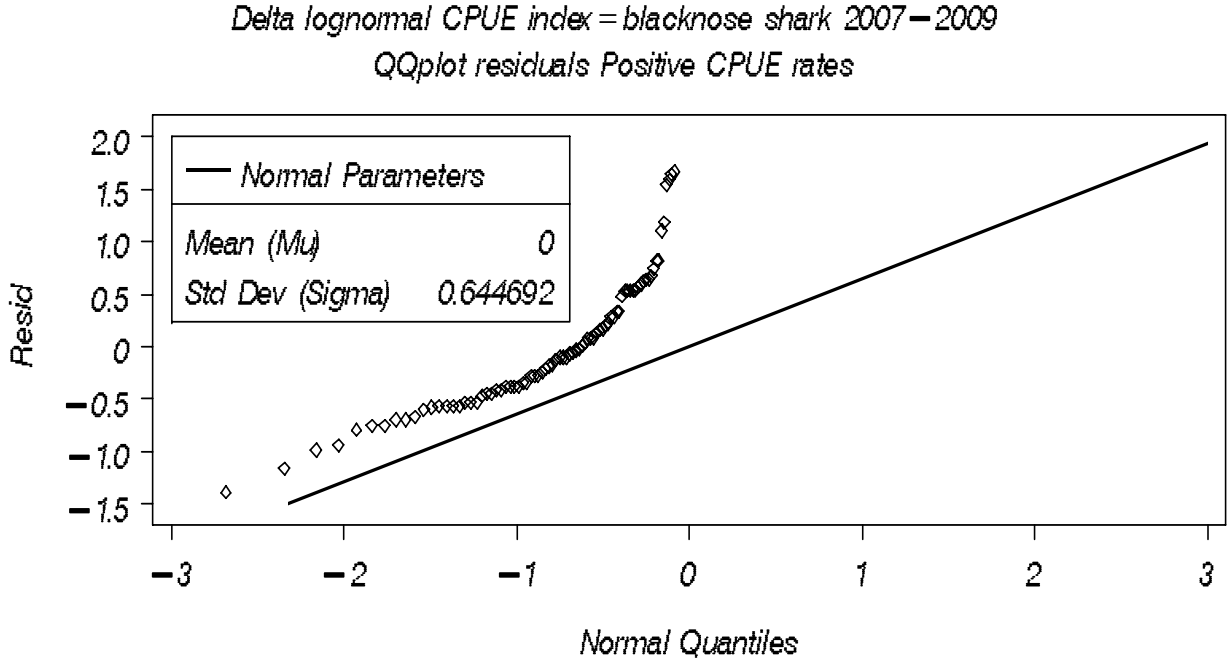


Figure 17. 2007-2009 SCDNR red drum survey blacknose shark nominal (obscpue2) and estimated (STDCPUE2) indices divided by the maximum values with 95% confidence limits (LCL2, UCL2).