SEDAR 21 DATA WORKSHOP DOCUMENT

Standardized catch rates for blacknose, dusky and sandbar sharks caught during a UNC longline survey conducted between 1972 and 2009 in Onslow Bay, NC.

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Summary

This document details the blacknose, sandbar and dusky shark catch from the University of North Carolina bottom longline survey conducted biweekly from April-November, 1972-2009, at two fixed stations in Onslow Bay south of Shackleford Banks, North Carolina. Catch per unit effort (CPUE) by set in number of sharks/number of hooks were examined by year. The CPUE 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. All three species show a declining trend from the mid 1970s to the mid 1990s followed by a more stable trend into the 2000s.

Introduction

In North Carolina waters information about sharks was limited prior to 1972. This led to the establishment of a bi-weekly longline survey (April-November, 1972-2009) conducted at two fixed stations south of Shackleford Banks in Onslow Bay, North Carolina by the University of North Carolina (UNC), Institute of Marine Sciences. The survey's objective was to define what sharks occurred in the area, their sizes, life stages, relative abundances and seasonal occurrences. Relative abundance indices from this survey have been previously generated for blacknose, dusky and sandbar sharks covering the time period from 1972 to 2005 (Schwartz et al. 2007). In this document, these time series are updated with data through 2009, including recovered temperature data and data corrections detailing missing water hauls and missing or incorrect information pertaining to individual animal records.

Methods

Sampling gear

An unanchored longline, approximately 4.8 km long of braided nylon (about 7.6 mm diameter) was suspended by orange 1.3 m diameter polyfoam plastic floats spaced every 10 hooks, spacing between hooks was 4.5 m. Gangions were 1.8 m long of No. 2 (95 kg) porch swing chain terminating in a No. 9 Mustad tuna hook. This gear was not altered throughout the 30 + years of sampling. The number of hooks varied more during early sample years and less during later years, rarely less than 100 hooks per set. Bait was fresh fish trawled near Beaufort Inlet, North Carolina, usually consisting of spot *Leiostomus xanthus* and Atlantic croaker *Micropogonias undulatus*, occasionally pigfish *Orthopristis chrysptera* and pinfish *Lagodon rhombiodes*.

Survey design

A bi-weekly shark survey occurred between April and November at two fixed stations 1-3.4 km south of Shackleford Banks in Onslow Bay, NC. The daily sampling protocol generally included an early morning set at the east-west (E-W) station, followed by a later set in the day at the north-south (N-S) station. The shallow (13 m) E-W set was over sandy-silt and the deeper (22 m) N-S set was primarily over sandy areas. Weather occasionally prevented occupying both stations on a single day, affecting about 17% (87) of 498 sampling days. Soak time was one hour, to avoid longer intervals that would often produce dead or dying sharks. Surface water temperatures were recorded at the beginning of the set. Fork length and sex were recorded for each shark species caught. Any specimen that was partially eaten, damaged or lost during line retrieval was counted but not measured.

Data Analysis

Catch per unit effort (CPUE) in number of sharks per hook were used to examine the relative abundance of blacknose, dusky and sandbar sharks caught during the UNC longline survey conducted between 1972 and 2009 in Onslow Bay, NC. 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 the CPUE for these analyses were: year (1972 – 2009), month (April – November), station (E-W, N-S), and temperature (<20 deg C, 20-24 deg C, 25-29 deg C, and 30+ deg C). The proportion of sets with positive CPUE values was modeled assuming a binomial distribution with a logit link function and the positive CPUE 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 providing 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

Survey Effort

Inter-annual variability existed in numbers of sets and total and average number of hooks fished (Figure 1). Effort appears to have peaked between 1975 and 1989, when between 24 and 32 sets were made each year, whereas between 1990 and 2009, there were only four years in which greater than 24 sets were made and the maximum during that time frame was 28 sets in one year. The frequency of observations (sets conducted) by factor and level used in the development of the standardized indices of abundance are reported in Table 1.

Blacknose sharks

A total of 1379 blacknose sharks were caught during 908 longline sets from 1972 to 2009. The size range of blacknose sharks caught by year is displayed in Figure 2. The proportion of sets with positive catch (at least one blacknose shark caught) was 35%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 2. Model diagnostic plots reveal that the model fit is acceptable (Figures 3a and 3b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 3 and are plotted by year in Figure 4.

Dusky sharks

A total of 1049 dusky sharks were caught during 908 longline sets from 1972 to 2009. The size range of dusky sharks caught by year is displayed in Figure 5. The proportion of sets with positive catch (at least one dusky shark caught) was 18%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 4. Model diagnostic plots reveal that the model fit is acceptable (Figures 6a and 6b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 5 and are plotted by year in Figure 7.

Sandbar sharks

A total of 312 sandbar sharks were caught during 908 longline sets from 1972 to 2009. The size range of sandbar sharks caught by year is displayed in Figure 8. The proportion of sets with positive catch (at least one sandbar shark caught) was 12%. The stepwise construction of each model and the resulting statistics for the mixed models are detailed in Table 6. Model diagnostic plots reveal that the model fit is acceptable (Figures 9a and 9b). The resulting indices of abundance based on the year effect least square means, associated statistics and nominal indices are reported in Table 7 and are plotted by year in Figure 10.

Literature Cited

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.

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Lo, N.C., L.D. Jacobson, and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci. 49:2515-2526.

Schwartz, F.J., C.T. McCandless, and J.J. Hoey. 2007. Trends in relative abundance for shark species caught during a UNC longline survey conducted between 1972 and 2005 in Onslow Bay, NC. SEDAR 13-DW-34. 79 pp.

Table 1. Percent frequency of observations (sets conducted) by factor and level used in the development of the standardized indices of abundance.

FACTOR	**LEVEL**	**%FREQ**
YEAR	1972	0.4
	1973	1.2
	1974	1.9
	1975	2.6
	1976	2.9
	1977	3.3
	1978	3.2
	1979	3.3
	1980	3.2
	1981	3.5
	1982	3.4
	1983	3.6
	1984	3.7
	1985	3.3
	1986	3.3
	1987	2.8
	1988	3.6
	1989	3.1
	1990	2.5
	1991	2.3
	1992	1.8
	1993	2.2
	1994	3.1
	1995	2.2
	1996	2.4
	1997	2.8
	1998	2.6
	1999	2.8
	2000	2.4
	2001	1.7
	2002	2.5
	2003	2.4
	2004	2.1
	2005	2.3
	2006	3.1
	2007	2.5
	2008	2.3
	2009	1.7
		100

FACTOR	**LEVEL**	**%FREQ**
MONTH	April	7.2
	May	16.2
	June	16.4
	July	15.3
	August	13.8
	Septemer	14.5
	October	14.2
	November	2.4
		100
STATION	E-W	54
	N-S	46
		100
TEMP deg C	<20	16.5
	20-24	29
	25-30	49.7
	30+	1.7
	no data	3.1
		100

Table 2. Results of the stepwise procedure for development of the catch rate model for blacknose 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	787	1036.8404	1.3175				
MONTH	780	888.3633	1.1389	13.5560	13.5560	148.48	<.0001
TEMP	783	926.9518	1.1823	10.2619		109.81	<.0001
STATION	786	982.7647	1.2503	5.1006		54.08	<.0001
YEAR	750	960.121	1.2802	2.8311		76.72	0.0001
MONTH +							
YEAR	743	778.5490	1.0478	20.4706	6.9146	109.81	<.0001
STATION	779	825.5568	1.0598	19.5598		62.81	<.0001
TEMP	776	882.0225	1.1366	13.7306		6.34	0.1751
MONTH + YEAR +							
STATION	742	711.4995	0.9589	27.2182	6.7476	67.05	<.0001
MONTH + YEAR + STATION							
YEAR*MONTH	530	459.9999	0.8679	34.1252	6.9070	Negative of Hessian not positive definite	
YEAR*STATION	706	649.0139	0.9193	30.2239		Negative of Hessian not positive definite	
MONTH*STATION	735	694.1241	0.9444	28.3188		Negative of Hessian not positive definite	

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + YEAR + STATION	2870.9	2875.2	2868.9

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

Significance (Pr>Chi) of Type 3	MONTH	YEAR	STATION
test of fixed effects for each factor	<.0001	0.0002	<.0001
DF	6	37	1
CHI SQUARE	72.73	75.66	49.44

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	289	272.3419	0.9424				
YEAR	252	187.4597	0.7439	21.0632	21.0632	108.31	<.0001
TEMP	286	257.7697	0.9013	4.3612		15.95	0.0012
MONTH	283	258.0738	0.9119	3.2364		15.61	0.0160
STATION	288	269.5879	0.9361	0.6685		2.95	0.0860
YEAR +							
TEMP	249	175.1979	0.7036	25.3396	4.2763	19.62	0.0002
MONTH	246	174.6450	0.7099	24.6711		20.53	0.0022
YEAR + TEMP +							
MONTH	243	171.7857	0.7069	24.9894	-0.3502	5.70	0.4572
YEAR*TEMP	213	141.1741	0.6628	29.6689		62.62	0.0039

MIXED MODELS	AIC	BIC	(-2) Res Log Likelihood
YEAR + TEMP	700.2	703.7	698.2
*YEAR + TEMP + YEAR*TEMP*	*599.6*	*602.9*	*597.6*

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

Significance (Pr>Chi) of Type 3	YEAR	TEMP	YEAR*TEMP
test of fixed effects for each factor	<.0001	0.0157	0.0468
DF	37	3	36
CHI SQUARE	89.04	10.37	51.33

Table 3. 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 est cpue (CV).

year	n obs	obs pos	obs ppos	obs cpue	est cpue	LCI	UCI	CV
1972	3	2	0.6667	0.0279	0.0571	0.0126	0.2595	0.8798
1973	9	6	0.6667	0.0546	0.0885	0.0299	0.2620	0.5853
1974	15	4	0.2667	0.0147	0.0320	0.0069	0.1495	0.9003
1975	19	9	0.4737	0.0304	0.0393	0.0164	0.0941	0.4580
1976	25	11	0.4400	0.0171	0.0357	0.0132	0.0965	0.5302
1977	29	18	0.6207	0.0466	0.0565	0.0316	0.1008	0.2958
1978	23	12	0.5217	0.0331	0.0568	0.0291	0.1108	0.3437
1979	26	14	0.5385	0.0241	0.0320	0.0165	0.0620	0.3405
1980	25	14	0.5600	0.0175	0.0182	0.0095	0.0348	0.3322
1981	26	10	0.3846	0.0089	0.0091	0.0034	0.0244	0.5223
1982	31	19	0.6129	0.0105	0.0139	0.0078	0.0245	0.2913
1983	29	15	0.5172	0.0071	0.0115	0.0063	0.0210	0.3090
1984	30	16	0.5333	0.0142	0.0149	0.0079	0.0284	0.3291
1985	27	11	0.4074	0.0083	0.0085	0.0035	0.0205	0.4615
1986	22	6	0.2727	0.0057	0.0052	0.0015	0.0184	0.6974
1987	21	9	0.4286	0.0122	0.0101	0.0036	0.0285	0.5538
1988	25	7	0.2800	0.0239	0.0210	0.0068	0.0643	0.6071
1989	26	6	0.2308	0.0075	0.0075	0.0023	0.0247	0.6518
1990	19	4	0.2105	0.0037	0.0041	0.0010	0.0163	0.7845
1991	20	8	0.4000	0.0091	0.0096	0.0035	0.0262	0.5376
1992	15	6	0.4000	0.0206	0.0184	0.0057	0.0598	0.6445
1993	14	6	0.4286	0.0210	0.0171	0.0056	0.0519	0.6019
1994	20	5	0.2500	0.0112	0.0086	0.0024	0.0312	0.7155
1995	19	6	0.3158	0.0154	0.0043	0.0011	0.0170	0.7842
1996	22	6	0.2727	0.0114	0.0069	0.0020	0.0242	0.6902
1997	24	7	0.2917	0.0056	0.0034	0.0009	0.0134	0.7698
1998	23	4	0.1739	0.0022	0.0019	0.0004	0.0083	0.8506
1999	21	3	0.1429	0.0013	0.0023	0.0004	0.0122	1.0120
2000	21	4	0.1905	0.0019	0.0025	0.0006	0.0101	0.7953
2001	13	4	0.3077	0.0055	0.0040	0.0009	0.0173	0.8383
2002	21	4	0.1905	0.0031	0.0020	0.0005	0.0087	0.8543
2003	19	2	0.1053	0.0016	0.0013	0.0002	0.0080	1.1510
2004	17	4	0.2353	0.0029	0.0035	0.0009	0.0141	0.7969
2005	18	4	0.2222	0.0044	0.0037	0.0008	0.0166	0.8603
2006	25	8	0.3200	0.0044	0.0065	0.0023	0.0189	0.5713
2007	21	9	0.4286	0.0113	0.0152	0.0063	0.0368	0.4652
2008	20	4	0.2000	0.0035	0.0041	0.0010	0.0166	0.7959
2009	15	5	0.3333	0.0066	0.0081	0.0022	0.0294	0.7170

Table 4. Results of the stepwise procedure for development of the catch rate model for dusky 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	787	781.3716	0.9928				
MONTH	780	681.0588	0.8732	12.0467	12.0467	100.31	<.0001
TEMP	783	729.0305	0.9311	6.2147		52.34	<.0001
STATION	786	779.9968	0.9924	0.0403		1.37	0.2410
YEAR	750	636.1332	0.8482	14.5649		Negative of Hessian not positive definite	
MONTH +							
TEMP	776	670.1033	0.8635	13.0238	0.9770	10.96	0.0271
YEAR	743	517.3986	0.6964	29.8550		Negative of Hessian not positive definite	

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + YEAR	2989.9	2994.2	2987.9

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

Significance (Pr>Chi) of Type 3	MONTH	YEAR
test of fixed effects for each factor	<.0001	<.0001
DF	7	31
CHI SQUARE	84.00	84.81

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	154	225.6773	1.4654				
YEAR	122	156.2881	1.2811	12.5768	12.5768	56.95	0.0043
MONTH	147	198.7073	1.3518	7.7521		19.73	0.0062
TEMP	151	207.8019	1.3762	6.0871		12.79	0.0051
STATION	153	224.4927	1.4673	-0.1297		0.82	0.3664
YEAR +							
MONTH	115	114.534	0.9959	32.0390	19.4623	48.18	<.0001
TEMP	119	139.5984	1.1731	19.9468		17.50	0.0006
YEAR + MONTH +							
TEMP	112	111.3702	0.9944	32.1414	0.1024	4.34	0.2268
YEAR*MONTH	65	66.3539	1.0208	30.3398	-1.6992	84.61	0.0016

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
YEAR + MONTH	381.0	383.7	379.0

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

Significance (Pr>Chi) of Type 3	MONTH	YEAR
test of fixed effects for each factor	<.0001	<.0001
DF	7	32
CHI SQUARE	41.92	84.52

Table 5. Dusky 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 est cpue (CV).

year	n obs	obs pos	obs ppos	obs cpue	est cpue	LCI	UCI	CV
1972	3	3	1.0000	0.0273	.	.	.	.
1973	9	4	0.4444	0.0079	0.0168	0.0060	0.0469	0.5507
1974	15	8	0.5333	0.0565	0.0415	0.0180	0.0955	0.4355
1975	19	8	0.4211	0.0604	0.0845	0.0364	0.1962	0.4403
1976	25	6	0.2400	0.0242	0.0445	0.0159	0.1246	0.5507
1977	29	9	0.3103	0.0275	0.0529	0.0228	0.1227	0.4395
1978	23	4	0.1739	0.0090	0.0113	0.0031	0.0409	0.7134
1979	26	8	0.3077	0.0130	0.0132	0.0051	0.0337	0.4981
1980	25	4	0.1600	0.0177	0.0054	0.0015	0.0190	0.7015
1981	26	12	0.4615	0.0263	0.0399	0.0196	0.0812	0.3665
1982	31	16	0.5161	0.0206	0.0248	0.0139	0.0442	0.2962
1983	29	13	0.4483	0.0095	0.0181	0.0093	0.0352	0.3414
1984	30	11	0.3667	0.0178	0.0119	0.0055	0.0260	0.4041
1985	27	4	0.1481	0.0034	0.0017	0.0005	0.0060	0.7132
1986	22	6	0.2727	0.0082	0.0093	0.0034	0.0257	0.5418
1987	21	5	0.2381	0.0134	0.0083	0.0027	0.0256	0.6080
1988	25	6	0.2400	0.0072	0.0040	0.0013	0.0128	0.6299
1989	26	6	0.2308	0.0070	0.0058	0.0020	0.0171	0.5808
1990	19	3	0.1579	0.0008	0.0009	0.0002	0.0036	0.7934
1991	20	1	0.0500	0.0033	0.0074	0.0010	0.0554	1.3185
1992	15	0	0.0000	0.0000	.	.	.	.
1993	14	3	0.2143	0.0019	0.0017	0.0004	0.0070	0.7928
1994	20	3	0.1500	0.0038	0.0045	0.0011	0.0183	0.7913
1995	19	0	0.0000	0.0000	.	.	.	.
1996	22	1	0.0455	0.0003	0.0002	0.0000	0.0015	1.3139
1997	24	1	0.0417	0.0013	0.0007	0.0001	0.0054	1.3101
1998	23	0	0.0000	0.0000	.	.	.	.
1999	21	1	0.0476	0.0010	0.0007	0.0001	0.0048	1.3028
2000	21	1	0.0476	0.0005	0.0002	0.0000	0.0018	1.3124
2001	13	1	0.0769	0.0008	0.0004	0.0001	0.0032	1.3111
2002	21	2	0.0952	0.0017	0.0017	0.0003	0.0085	0.9541
2003	19	1	0.0526	0.0005	0.0003	0.0000	0.0019	1.3125
2004	17	2	0.1176	0.0047	0.0042	0.0008	0.0216	0.9804
2005	18	0	0.0000	0.0000	.	.	.	.
2006	25	1	0.0400	0.0004	0.0002	0.0000	0.0017	1.3078
2007	21	2	0.0952	0.0014	0.0009	0.0002	0.0044	0.9725
2008	20	1	0.0500	0.0005	0.0010	0.0001	0.0078	1.3207
2009	15	0	0.0000	0.0000	.	.	.	.

Table 6. Results of the stepwise procedure for development of the catch rate model for sandbar 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	787	587.9258	0.7470				
MONTH	780	535.7580	0.6869	8.0455	8.0455	52.17	<.0001
TEMP	783	574.9005	0.7342	1.7135		13.03	0.0112
STATION	786	581.8807	0.7403	0.8969		6.05	0.0139
YEAR	750	453.7395	0.6050	19.0094		Negative of Hessian not positive definite	
MONTH +							
STATION	779	529.7287	0.6800	8.9692	0.9237	6.03	0.0141
TEMP	776	532.9998	0.6869	8.0455		2.76	0.5991
YEAR	743	396.4927	0.5336	28.5676		Negative of Hessian not positive definite	

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
MONTH + YEAR	2496.4	2500.5	2494.4

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

	MONTH	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	<.0001
DF	7	24
CHI SQUARE	32.26	66.92

POSITIVE CATCHES-LOGNORMAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	CHISQ	PR>CHI
NULL	96	76.5735	0.7976				
YEAR	72	51.9553	0.7216	9.5286	9.5286	37.62	0.0379
STATION	95	75.2282	0.7919	0.7146		1.72	0.1898
TEMP	93	73.9515	0.7952	0.3009		3.38	0.3367
MONTH	89	71.1823	0.7998	-0.2758		7.08	0.4204

FINAL MODEL	AIC	BIC	(-2) Res Log Likelihood
YEAR	207.5	209.7	205.5

Type 3 Test of Fixed Effects for Final Model = YEAR

	YEAR
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	0.0826
DF	24
CHI SQUARE	34.12

Table 7. 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 est cpue (CV).

year	n obs	obs pos	obs ppos	obs cpue	est cpue	LCI	UCI	CV
1972	3	0	0.0000	0.0000	.	.	.	.
1973	9	0	0.0000	0.0000	.	.	.	.
1974	15	0	0.0000	0.0000	.	.	.	.
1975	19	0	0.0000	0.0000	.	.	.	.
1976	25	2	0.0800	0.0008	0.0012	0.0002	0.0062	1.0156
1977	29	9	0.3103	0.0122	0.0219	0.0096	0.0501	0.4317
1978	23	7	0.3043	0.0162	0.0182	0.0069	0.0481	0.5153
1979	26	12	0.4615	0.0135	0.0159	0.0076	0.0333	0.3808
1980	25	1	0.0400	0.0002	0.0003	0.0000	0.0025	1.3786
1981	26	2	0.0769	0.0008	0.0011	0.0002	0.0059	0.9998
1982	31	2	0.0645	0.0008	0.0008	0.0002	0.0046	1.0366
1983	29	11	0.3793	0.0090	0.0078	0.0035	0.0172	0.4130
1984	30	8	0.2667	0.0040	0.0056	0.0022	0.0140	0.4854
1985	27	8	0.2963	0.0051	0.0067	0.0027	0.0168	0.4849
1986	22	4	0.1818	0.0034	0.0020	0.0005	0.0085	0.8141
1987	21	7	0.3333	0.0106	0.0115	0.0045	0.0293	0.4945
1988	25	4	0.1600	0.0054	0.0046	0.0011	0.0191	0.8150
1989	26	3	0.1154	0.0045	0.0047	0.0011	0.0197	0.8165
1990	19	0	0.0000	0.0000	.	.	.	.
1991	20	2	0.1000	0.0005	0.0007	0.0001	0.0037	0.9942
1992	15	0	0.0000	0.0000	.	.	.	.
1993	14	2	0.1429	0.0010	0.0013	0.0002	0.0067	0.9837
1994	20	3	0.1500	0.0077	0.0109	0.0026	0.0454	0.8136
1995	19	1	0.0526	0.0004	0.0005	0.0001	0.0039	1.3696
1996	22	1	0.0455	0.0005	0.0006	0.0001	0.0045	1.3769
1997	24	2	0.0833	0.0013	0.0019	0.0004	0.0101	0.9938
1998	23	2	0.0870	0.0011	0.0015	0.0003	0.0082	1.0168
1999	21	1	0.0476	0.0005	0.0007	0.0001	0.0054	1.3735
2000	21	1	0.0476	0.0005	0.0006	0.0001	0.0044	1.3804
2001	13	0	0.0000	0.0000	.	.	.	.
2002	21	0	0.0000	0.0000	.	.	.	.
2003	19	0	0.0000	0.0000	.	.	.	.
2004	17	0	0.0000	0.0000	.	.	.	.
2005	18	0	0.0000	0.0000	.	.	.	
2006	25	1	0.0400	0.0004	0.0005	0.0001	0.0042	1.3787
2007	21	0	0.0000	0.0000	.	.	.	.
2008	20	1	0.0500	0.0005	0.0006	0.0001	0.0047	1.3783
2009	15	0	0.0000	0.0000	.	.	.	.

Figure 1. UNC shark longline survey effort from 1972-2009.

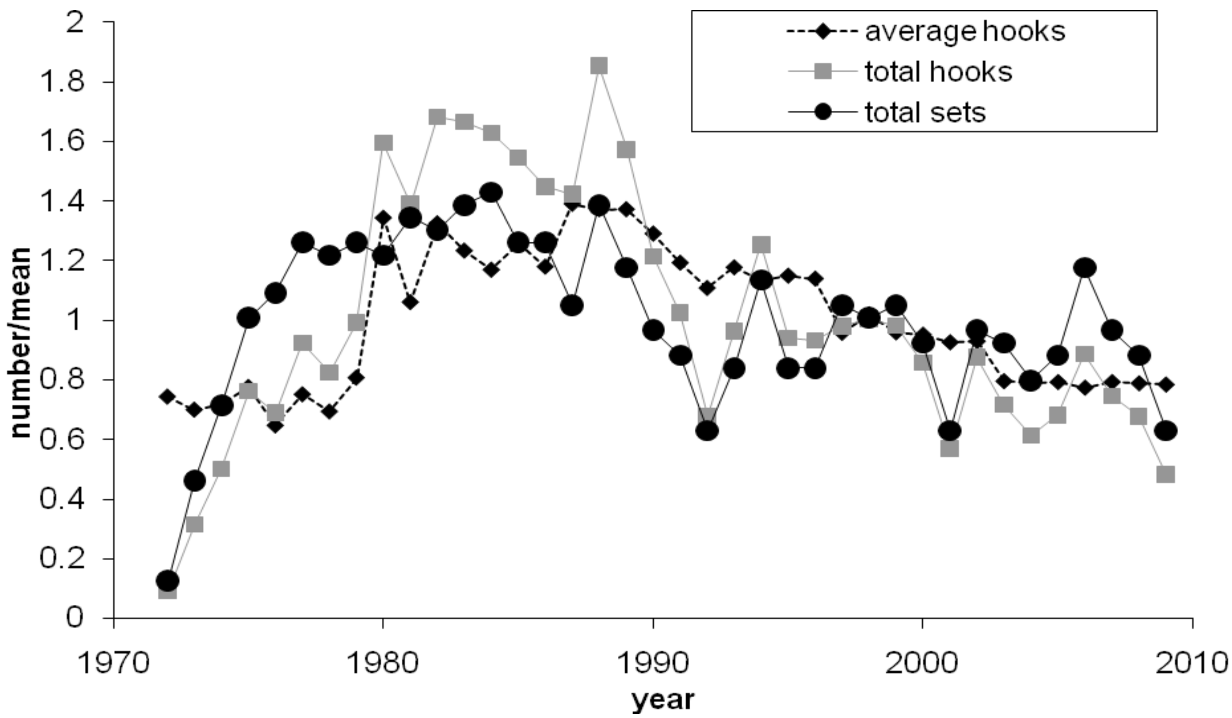


Figure 2. Fork lengths (cm) of blacknose sharks caught by year

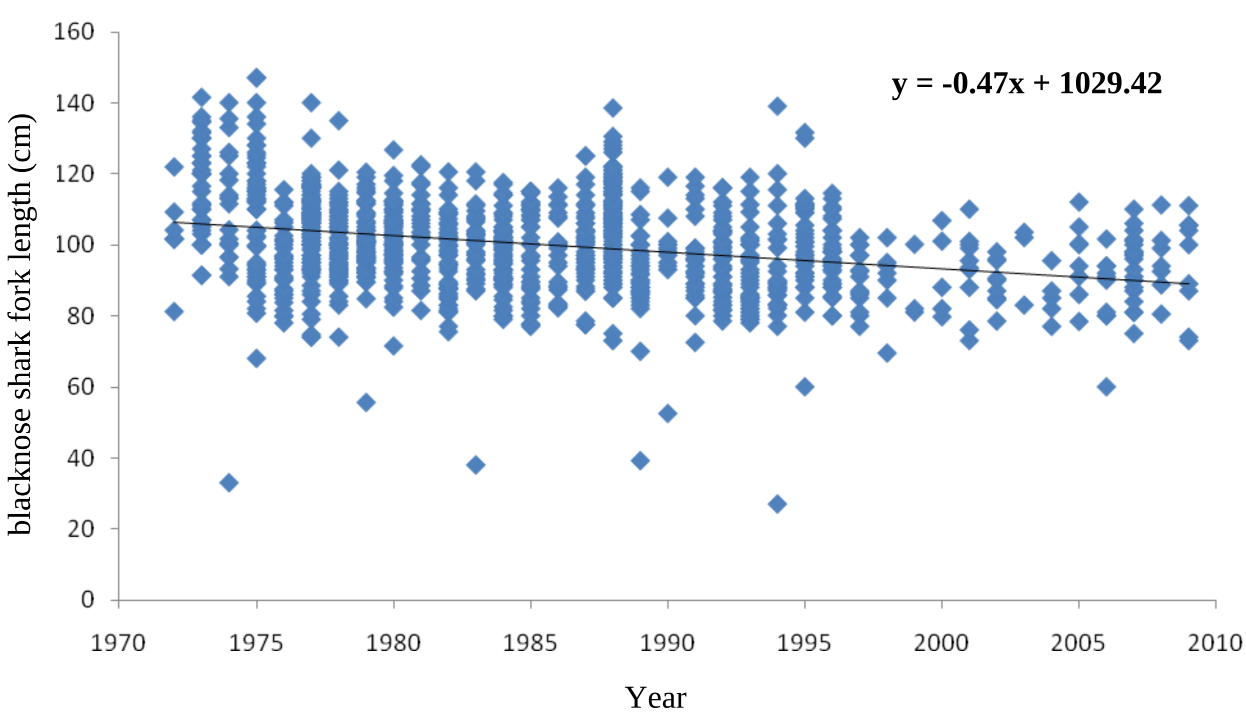
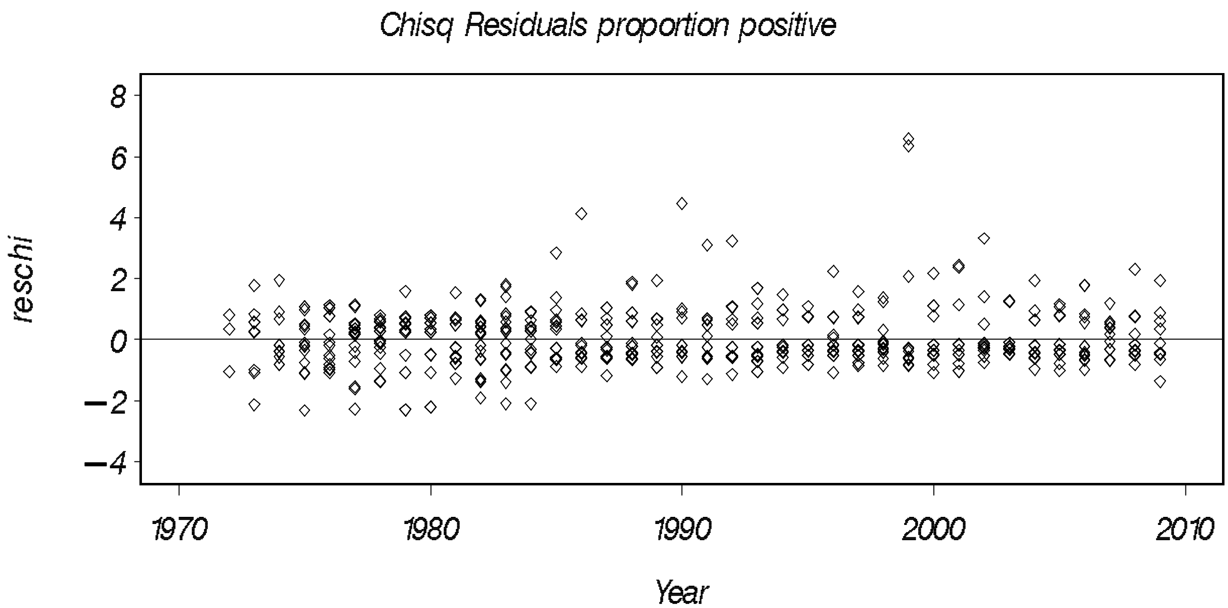


Figure 3a. Blacknose shark model diagnostic plots for the binomial component.



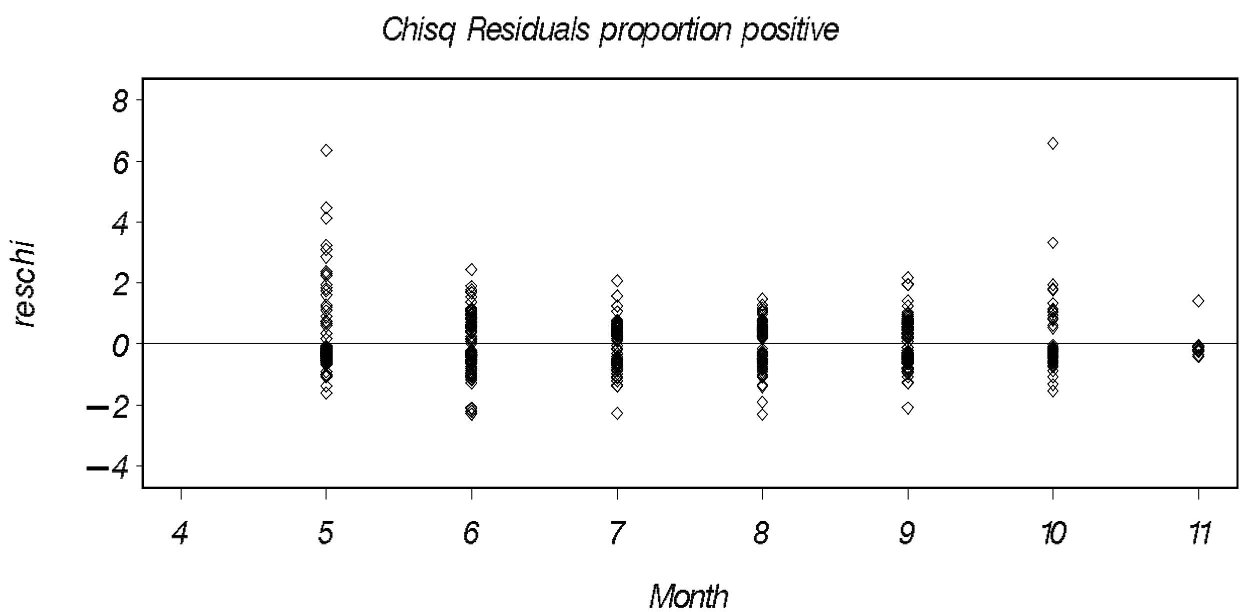
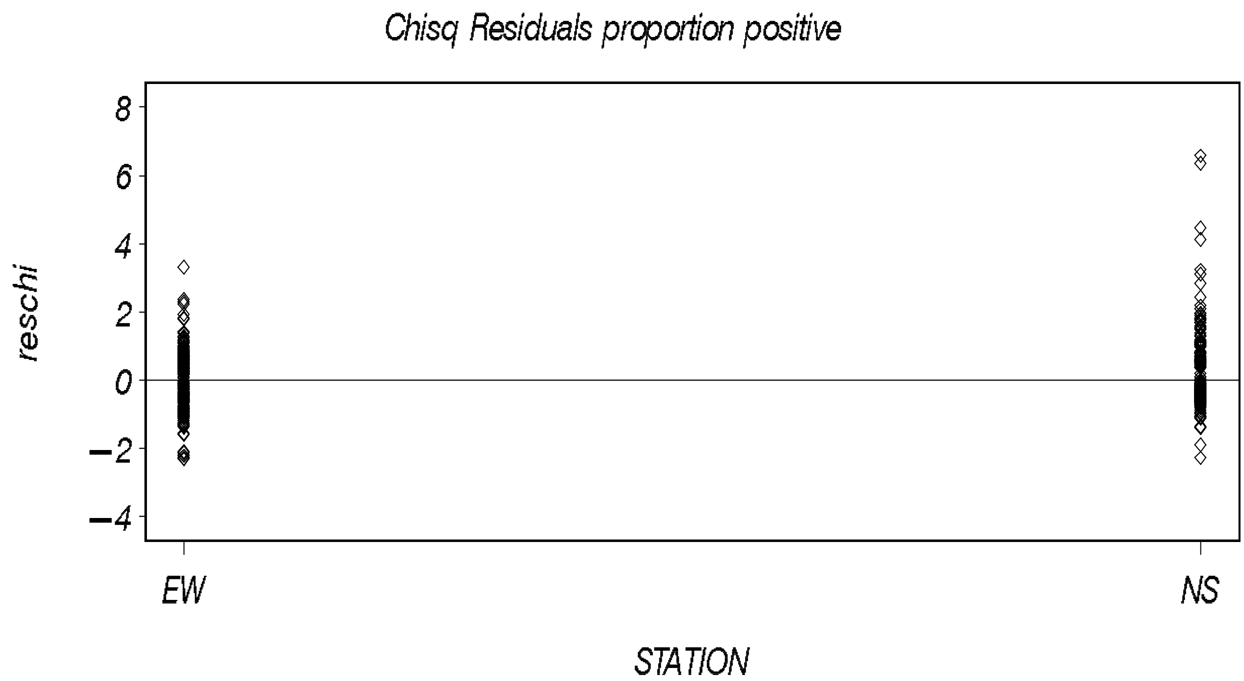
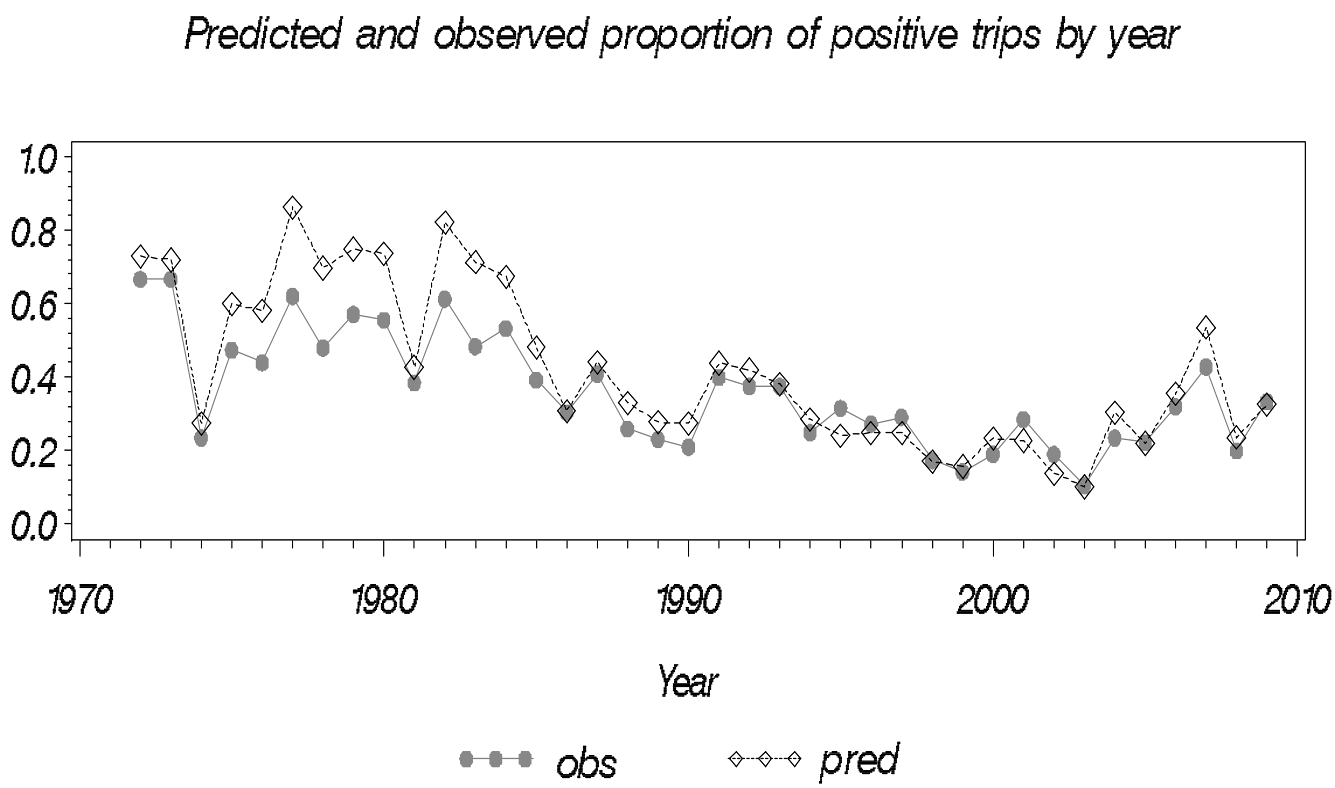
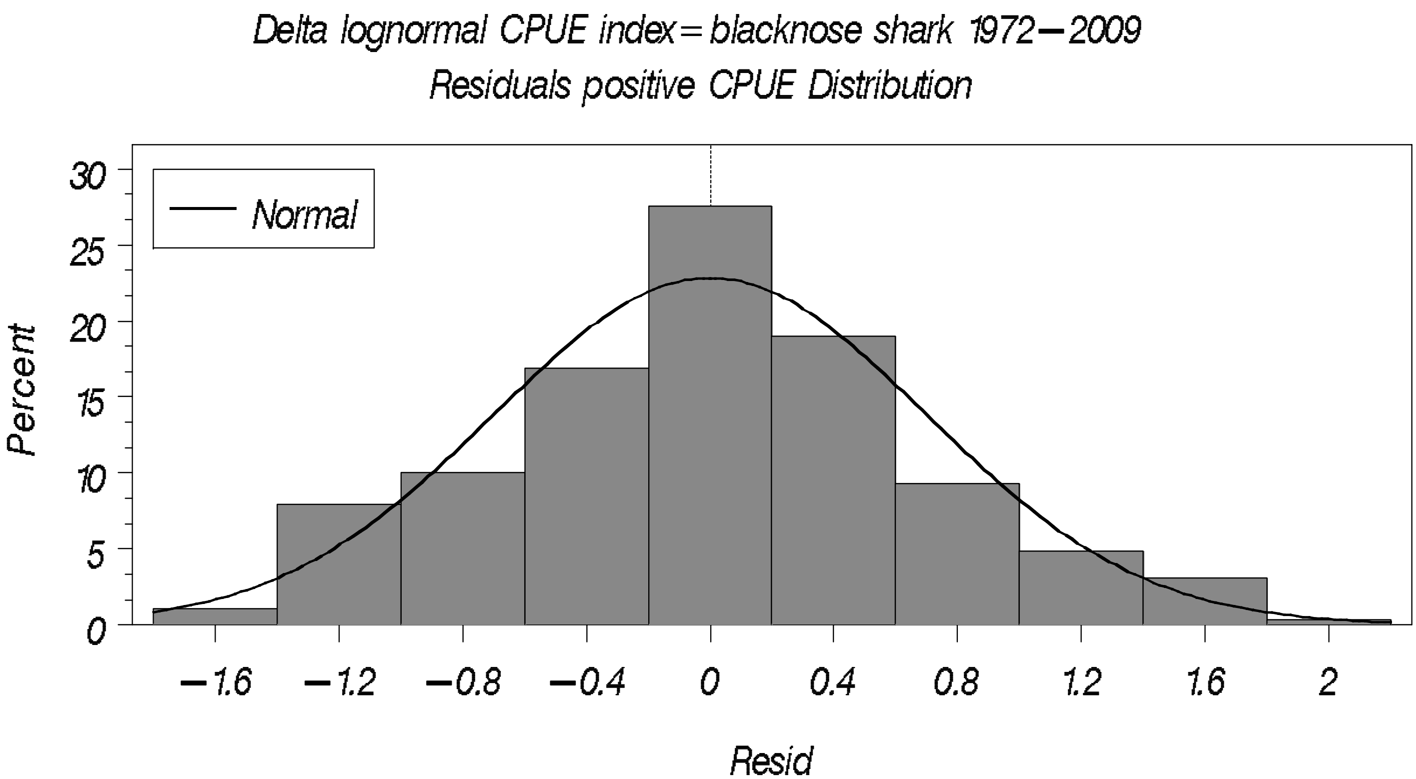


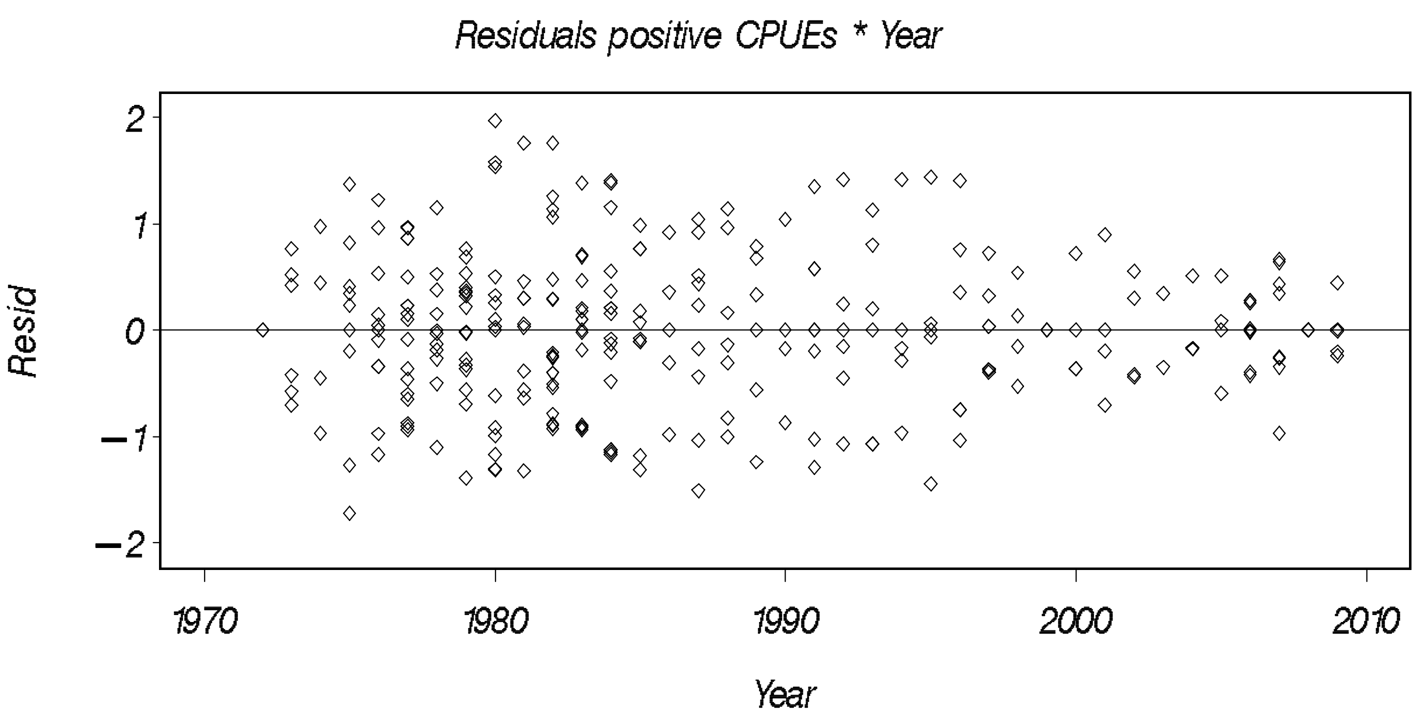
Figure 3a continued. Blacknose shark model diagnostic plots for binomial component.



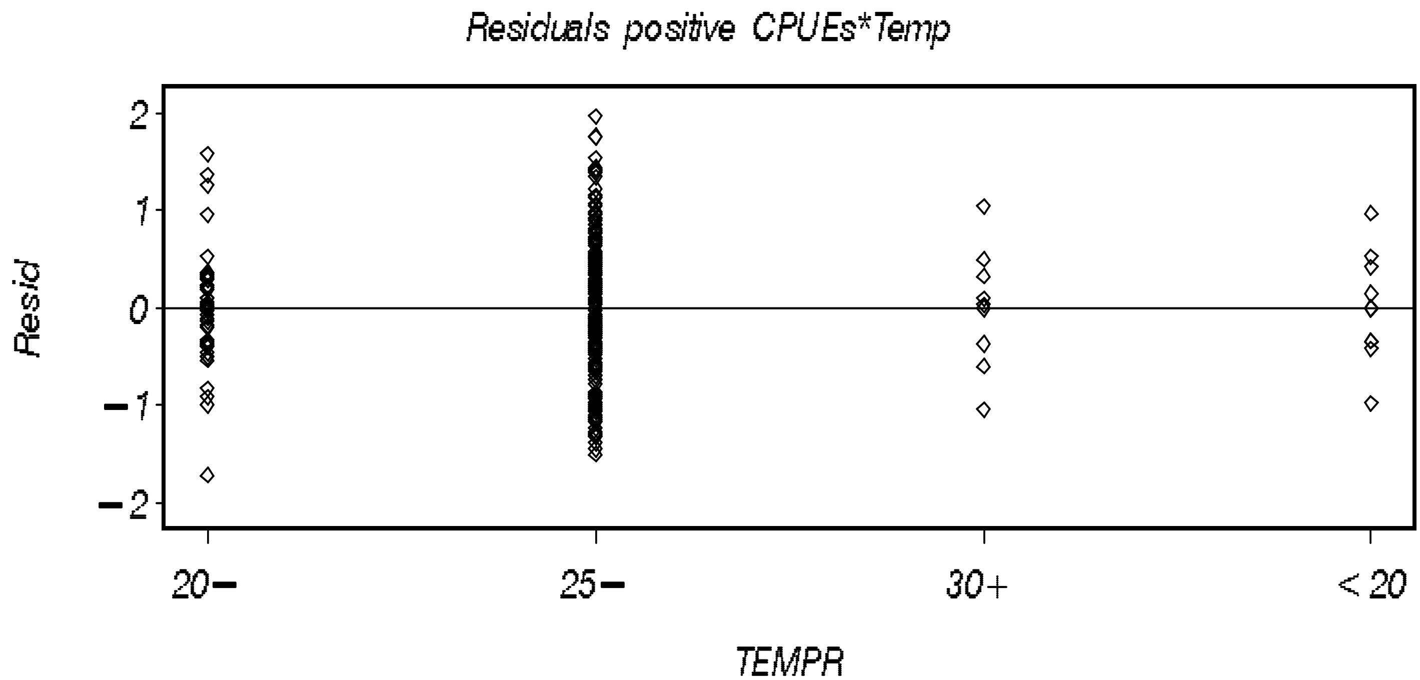


3b. Blacknose shark model diagnostic plots for lognormal component.





3b continued. Blacknose shark model diagnostic plots for lognormal component.



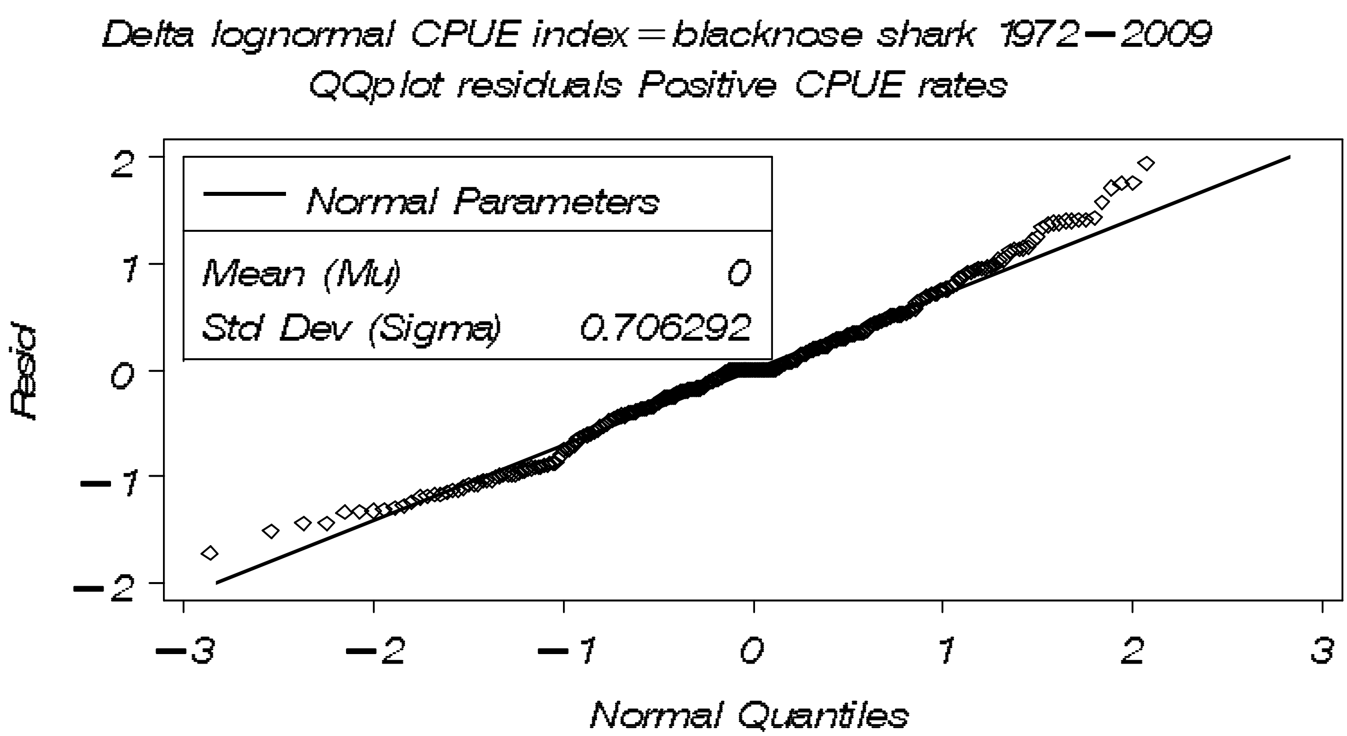


Figure 4. Blacknose shark nominal (obs cpue) and estimated (est cpue) indices divided by the maximum values with 95% confidence limits (LCL, UCL).

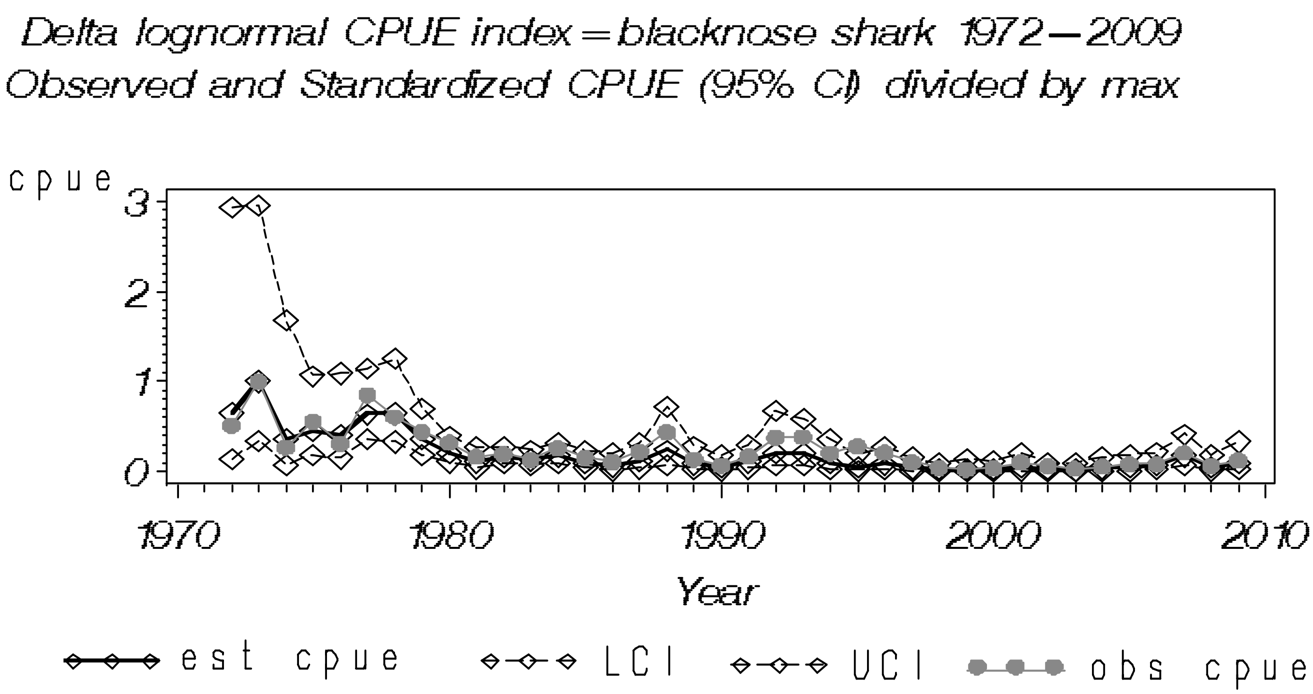


Figure 5. Fork lengths (cm) of dusky sharks caught by year

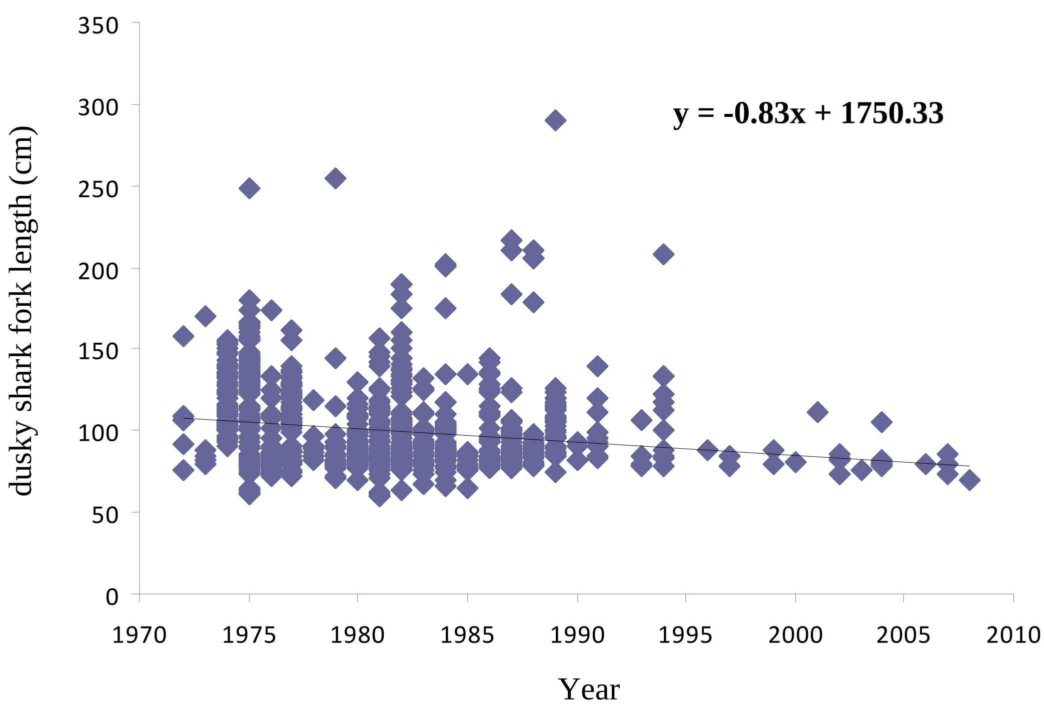
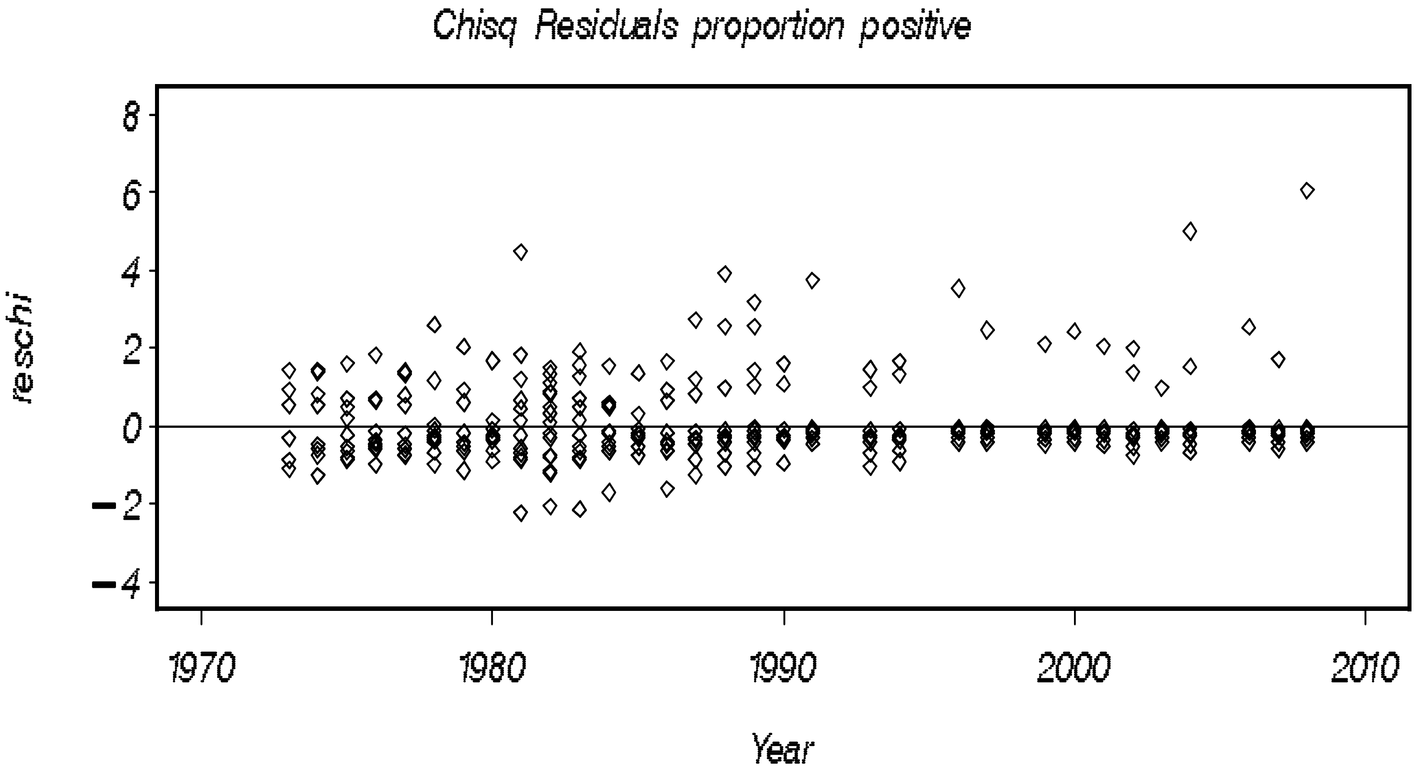


Figure 6a. Dusky shark model diagnostic plots for the binomial component.



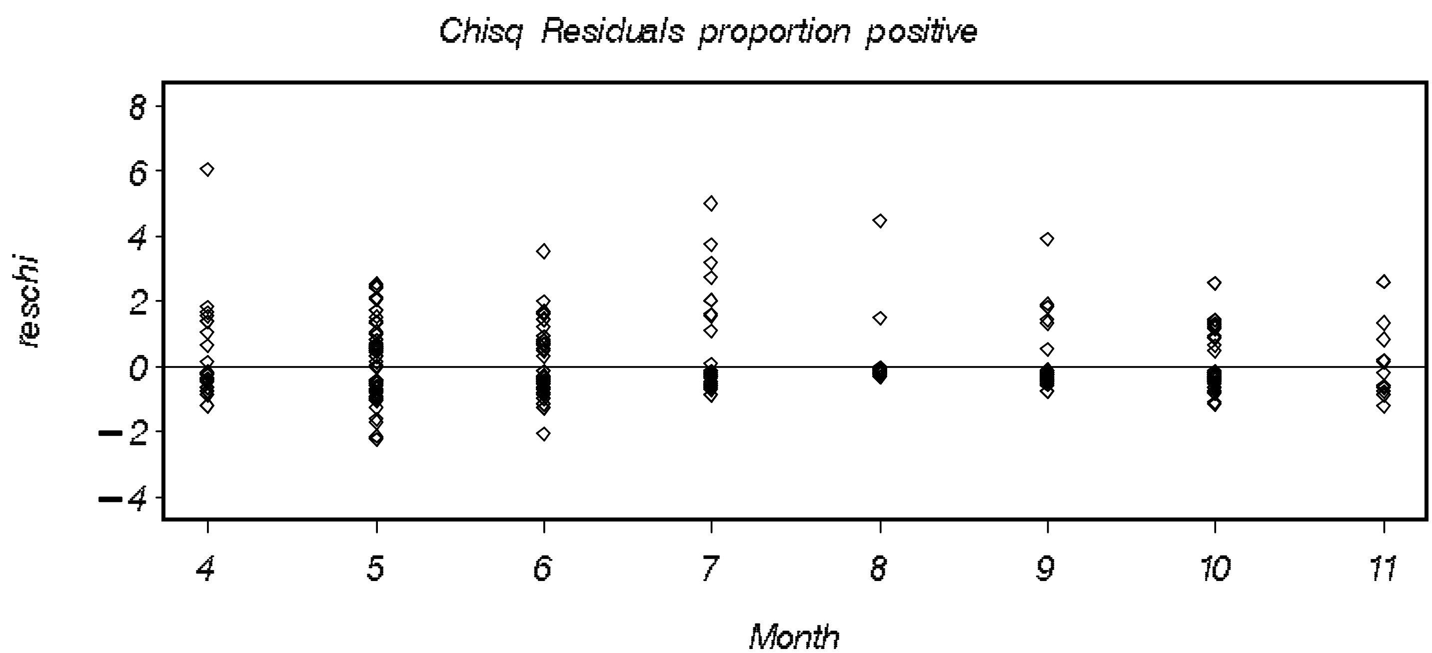


Figure 6a continued. Dusky shark model diagnostic plots for the binomial component.

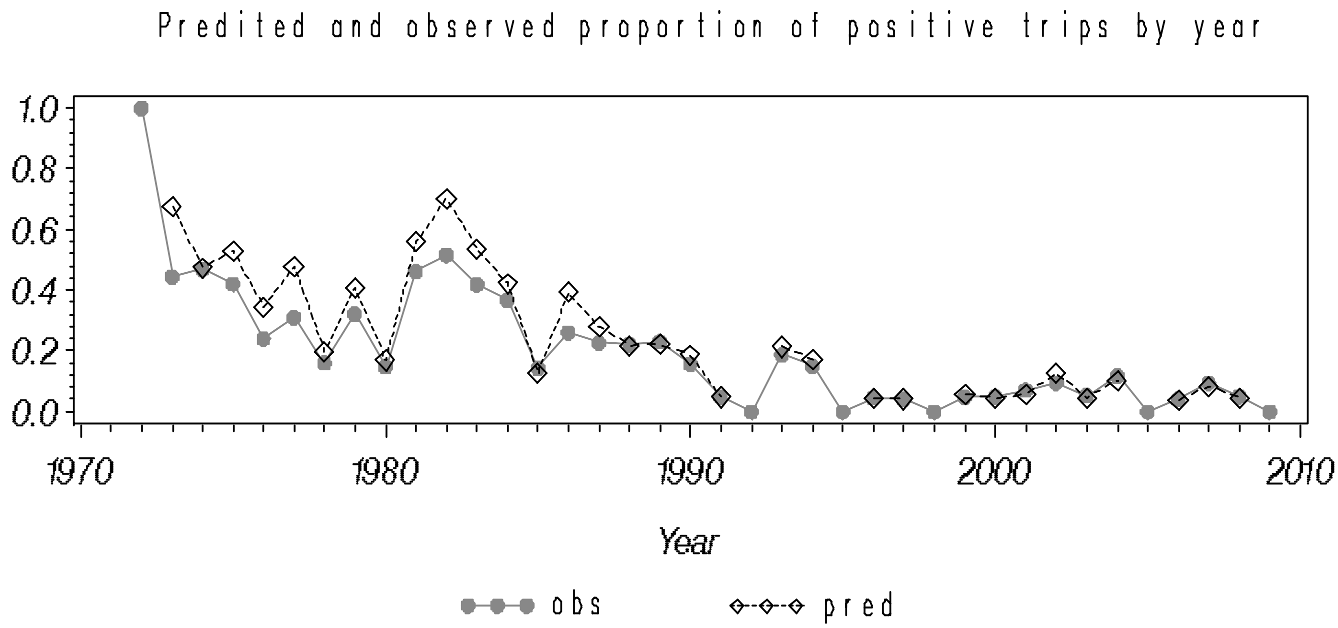


Figure 6b. Dusky shark model diagnostic plots for the lognormal component.

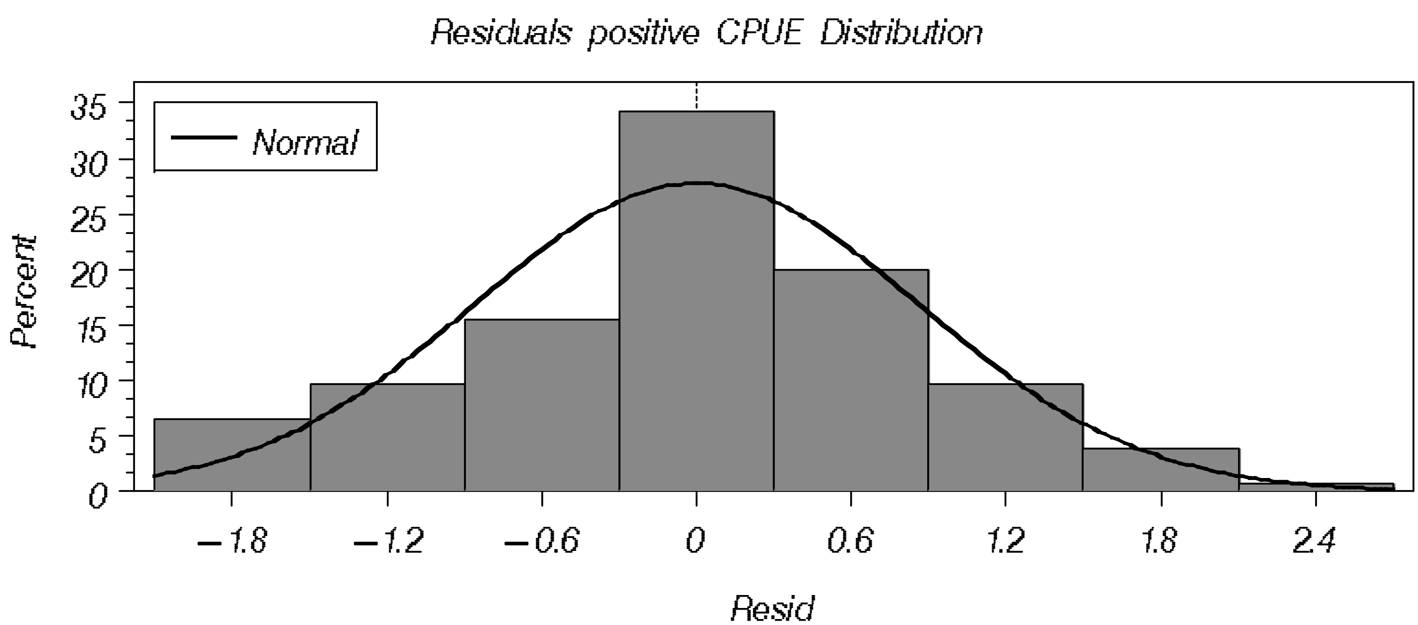
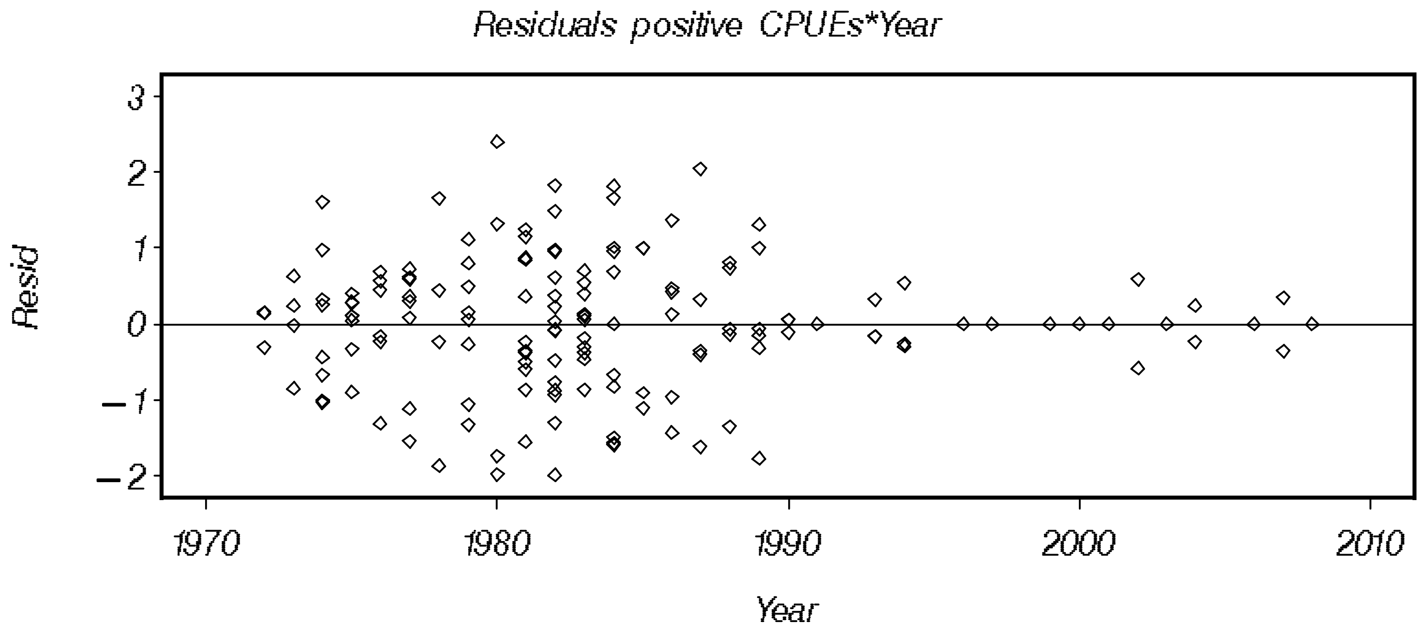


Figure 6b continued. Dusky shark model diagnostic plots for the lognormal component.



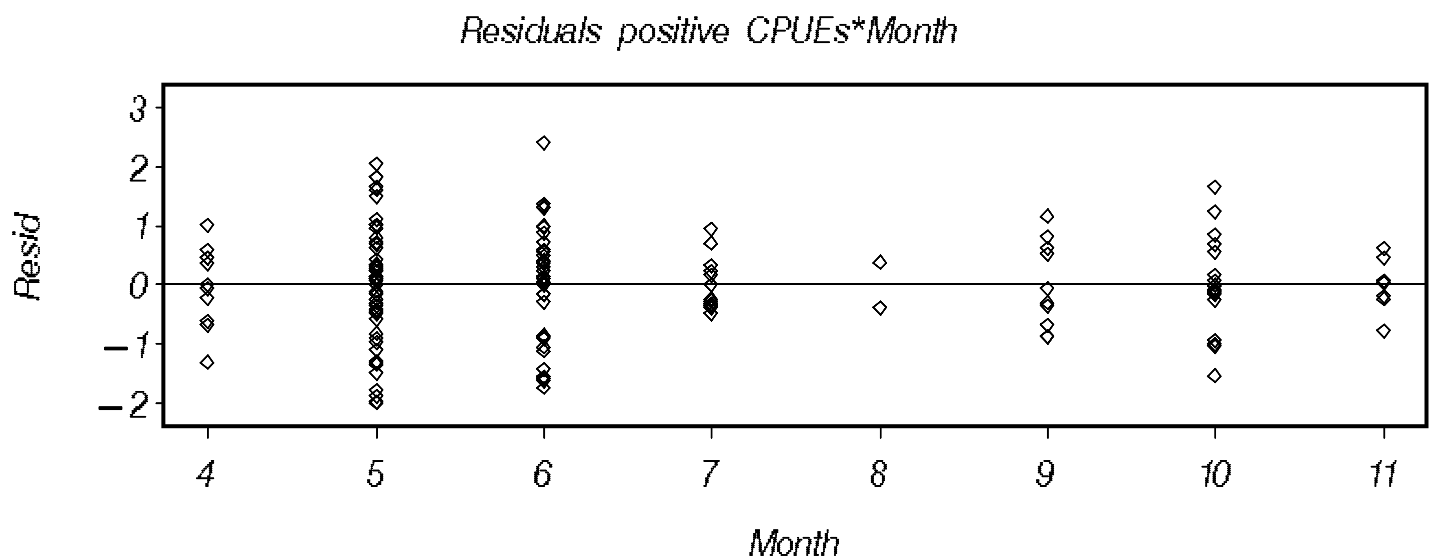


Figure 6b continued. Dusky shark model diagnostic plots for the lognormal component.

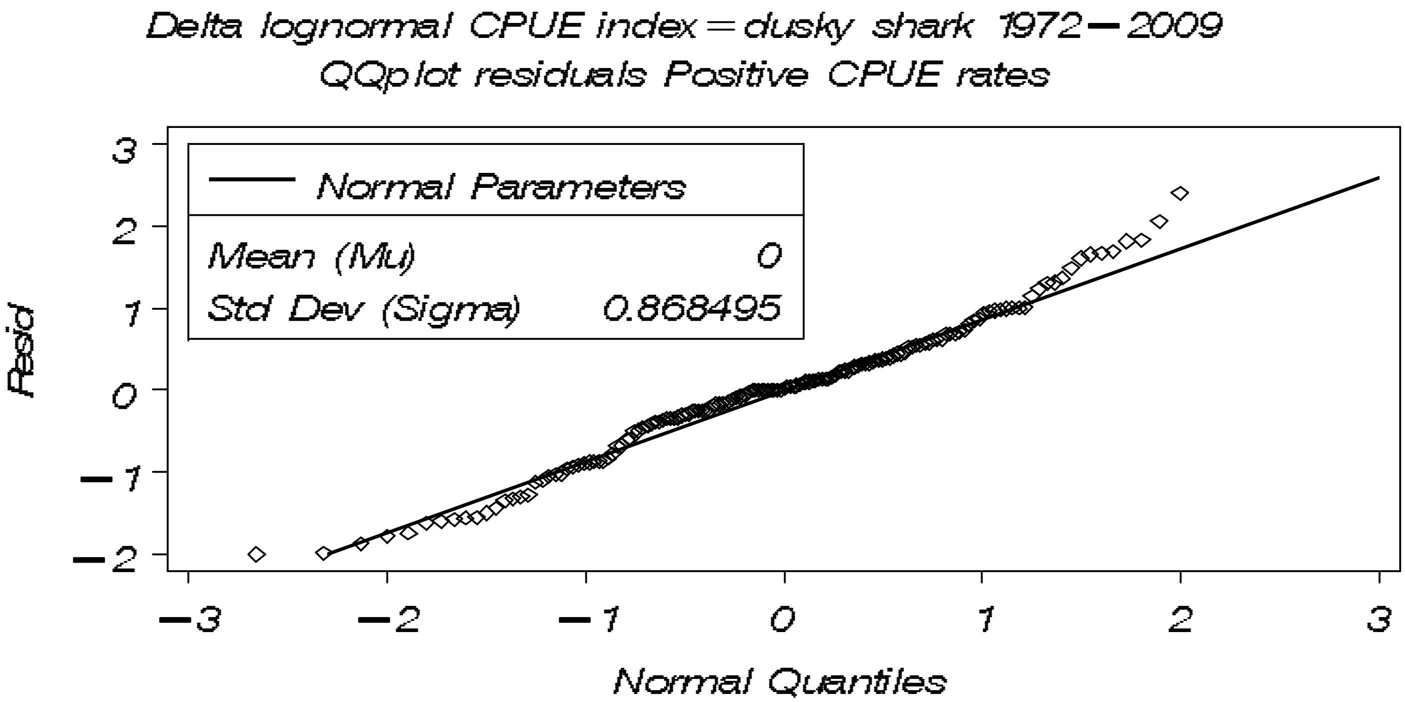


Figure 7. Dusky shark nominal (obs cpue) and estimated (est cpue) indices divided by the maximum values with 95% confidence limits (LCL, UCL).

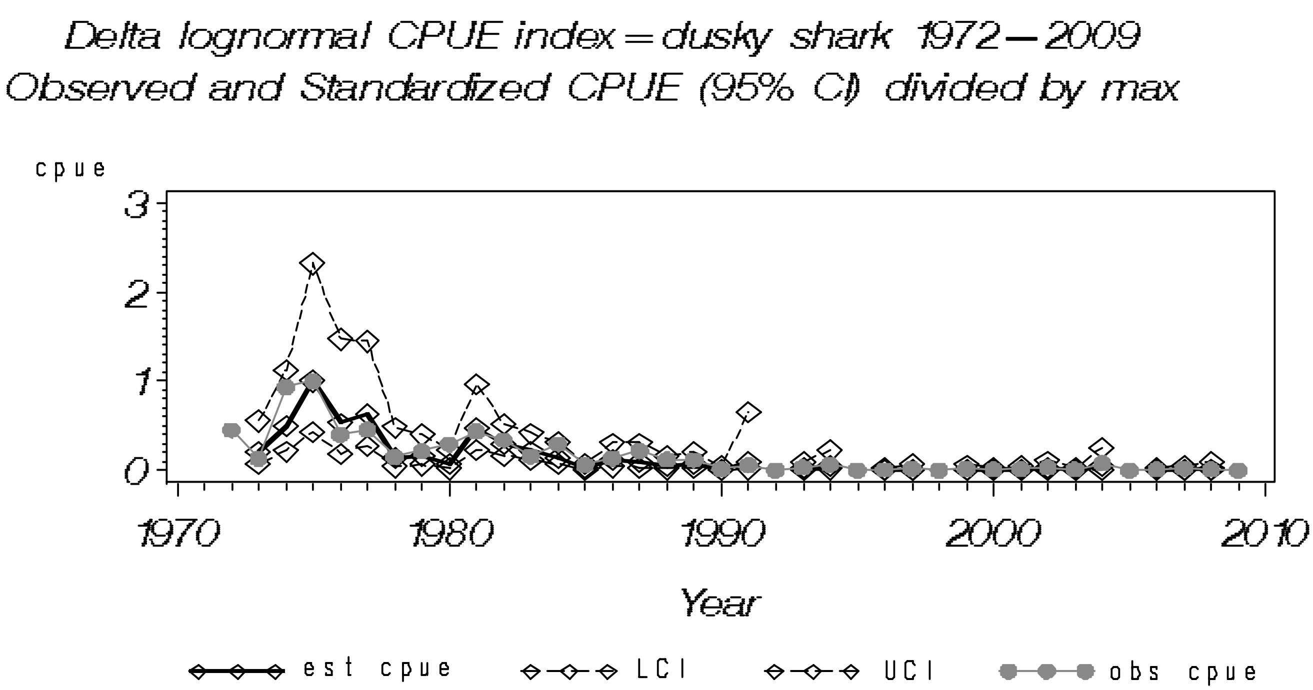


Figure 8. Fork lengths (cm) of sandbar sharks caught by year

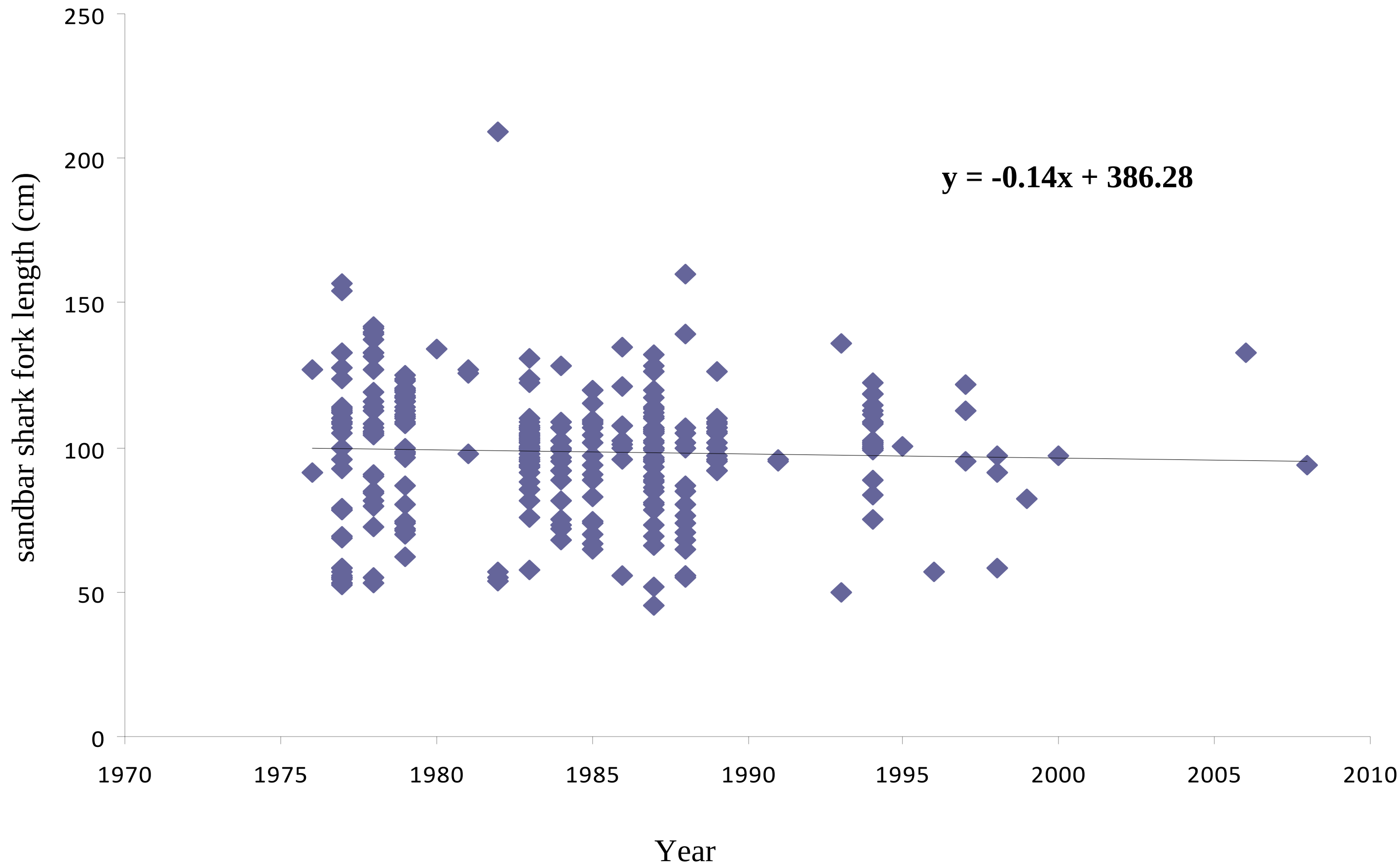


Figure 9a. Sandbar shark model diagnostic plots for the binomial component.

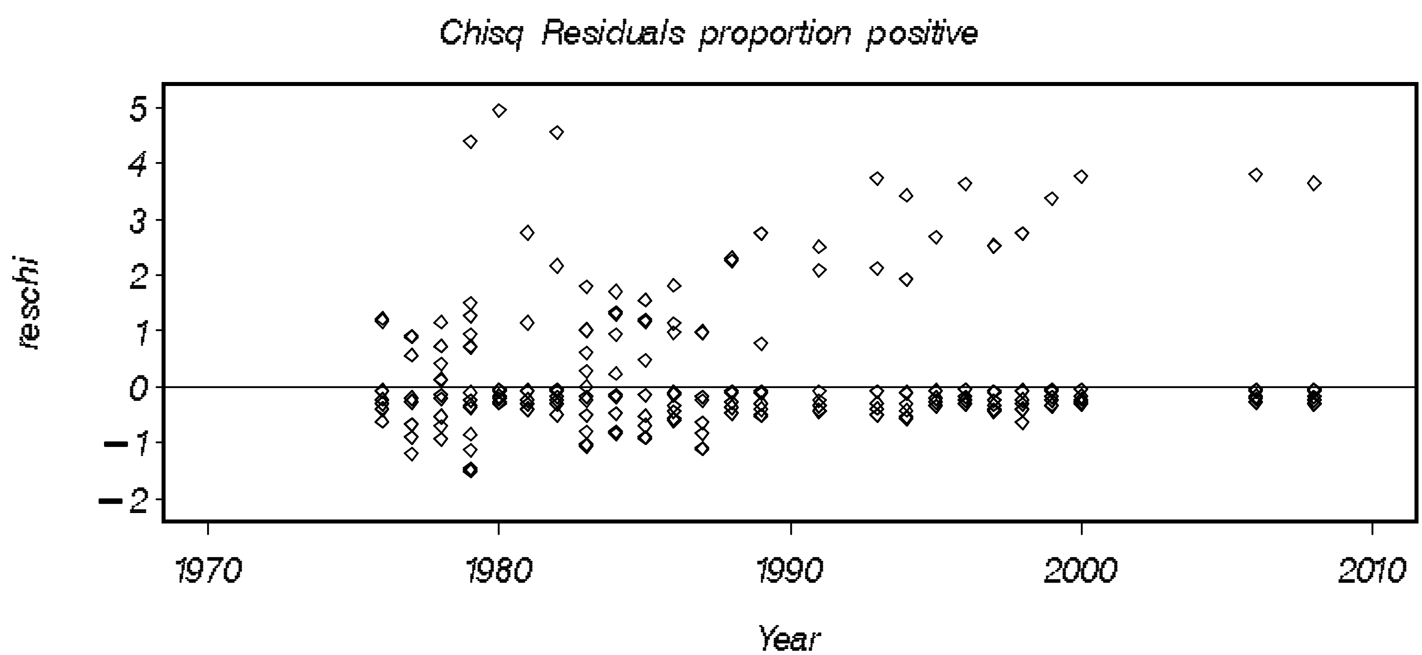
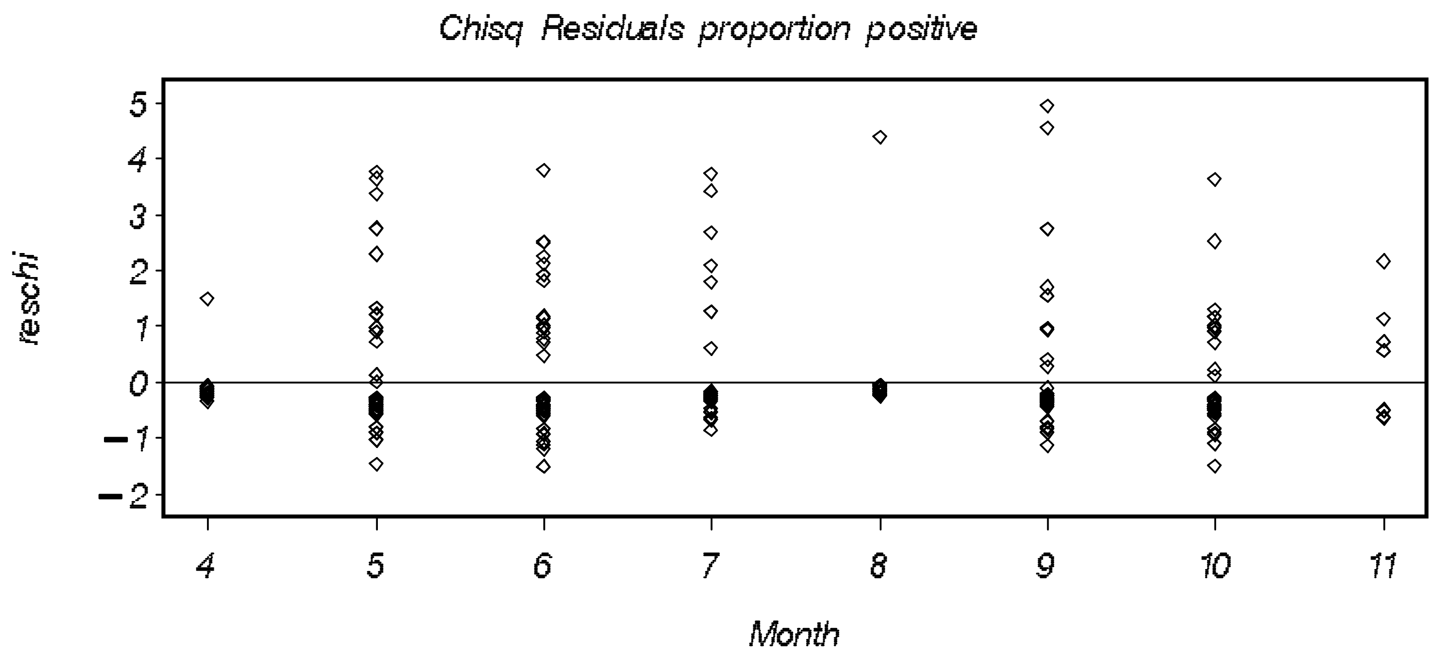


Figure 9a continued. Sandbar shark model diagnostic plots for the binomial component.



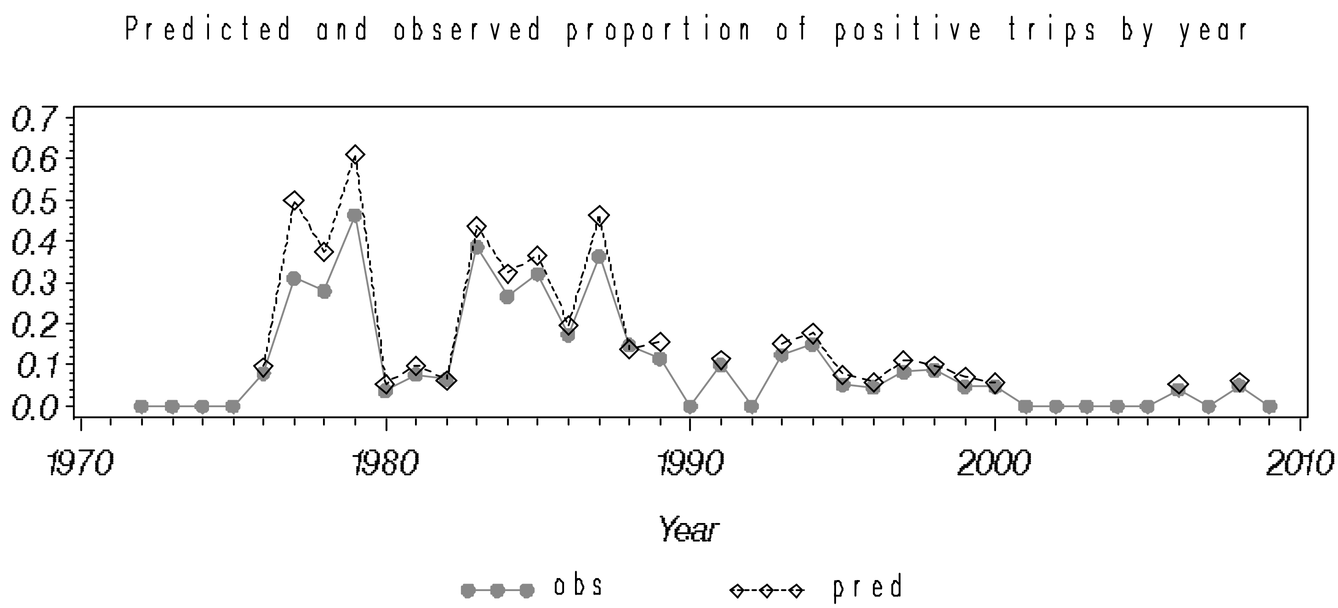
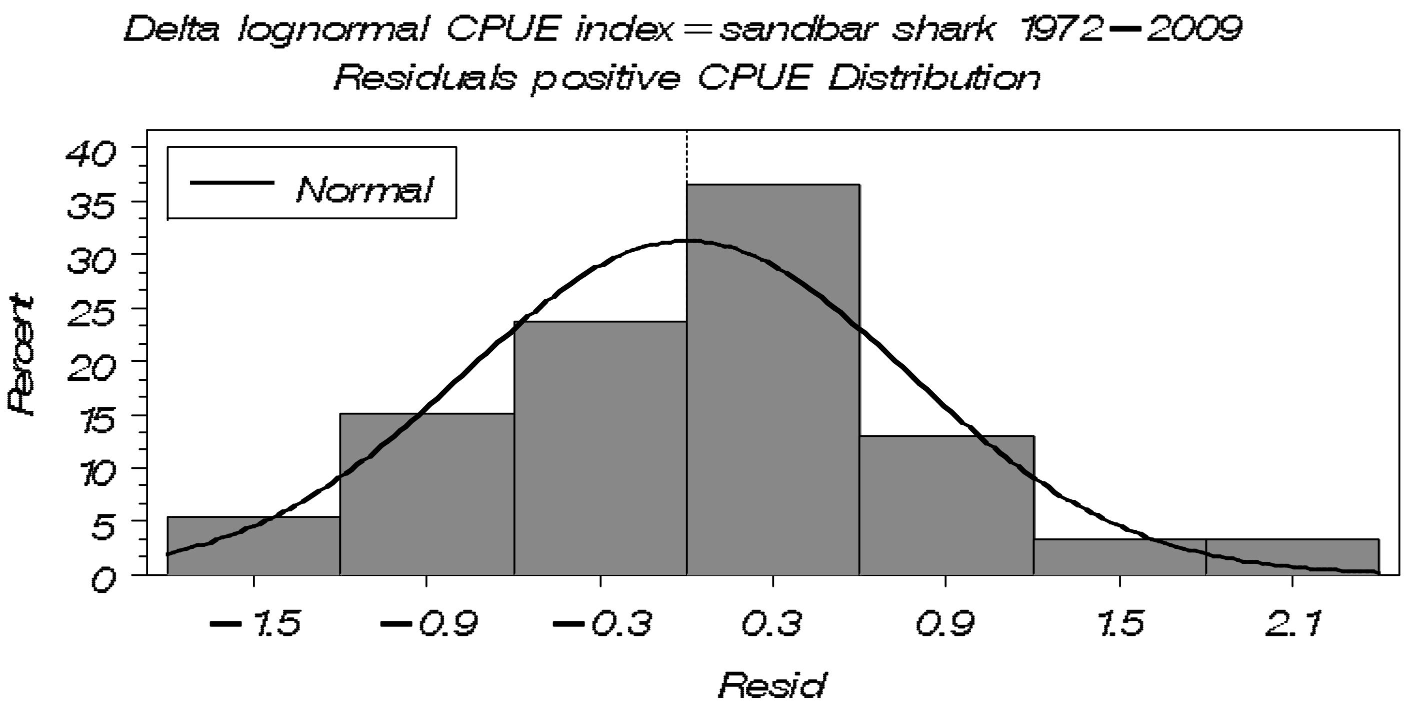


Figure 9b. Sandbar shark model diagnostic plots for the lognormal component.



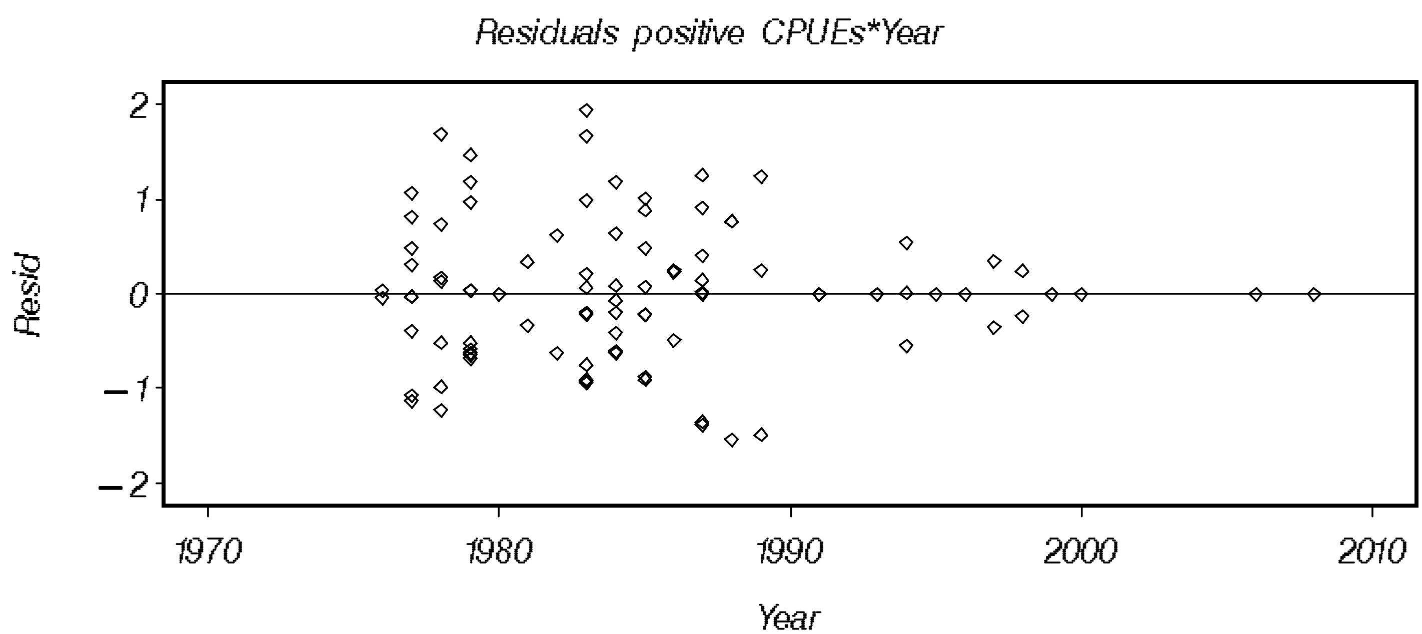


Figure 9b continued. Sandbar shark model diagnostic plots for the lognormal component.

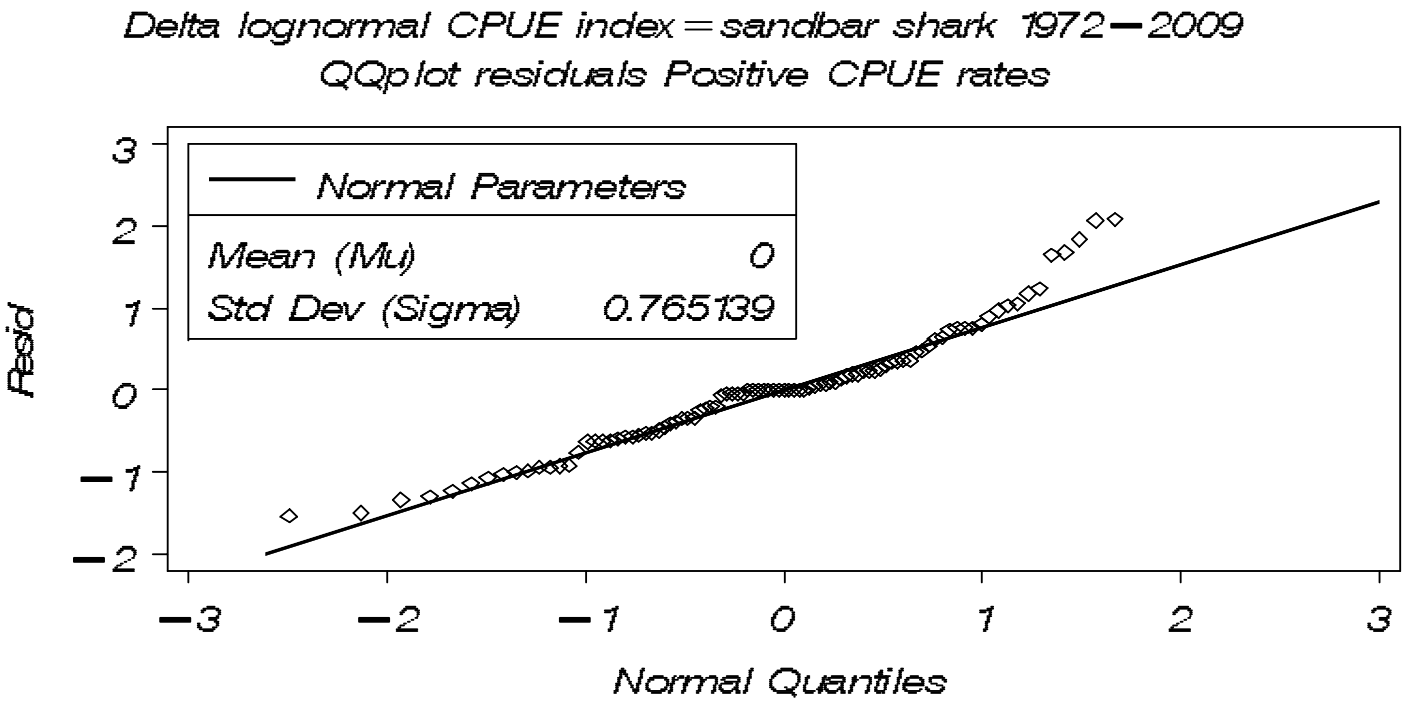


Figure 10. Sandbar shark nominal (obs cpue) and estimated (est cpue) indices divided by the maximum values with 95% confidence limits (LCL, UCL).