STANDARDIZED CATCH RATES OF SANDBAR AND BLACKNOSE SHARK FROM A FISHERY-INDEPENDENT GILLNET SURVEY IN NORTHWEST FLORIDA

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ABSTRACT

Fishery-independent catch rates were standardized using a two-part generalized linear model analysis. One part modeled the proportion of sets that caught any sharks (at least one shark was caught) assuming a binomial distribution with a logit link function while the other part modeled the catch rates of sets with positive catches assuming a lognormal distribution. Standardized indices were developed for sandbar shark and juvenile (age 1+) and adult for blacknose shark. Depending on species, the final models varied with factors area, season, year. Although factors such as area and season were significant in most models, results from this study indicate any bias associated with these aspects did not significantly change the trends between nominal and standardized data. Trends in abundance declined for sandbar shark, juvenile blacknose shark but were stable for adult blacknose shark.

INTRODUCTION

A fishery-independent survey of large and small coastal shark populations in coastal areas of the northeast Gulf of Mexico has been conducted using gillnets from 1996-2009. The present study attempts to standardize catch rates using a modified two-step approach originally proposed by Lo et al. (1992). Catch rate series are developed for sandbar and blacknose sharks. Additional catch rate series are also developed by life stage for blacknose shark.

MATERIAL AND METHODS

Field data collection

A 186-m long gill net consisting of six different mesh size panels was utilized for sampling. Stretched mesh sizes (SM) ranged from 8.9 cm (3.5”) to 14.0 cm (5.5”) in steps of 1.27 cm (0.5”), with an additional size of 20.3 cm (8.0”). Panel depths when fishing were 3.1 m. Webbing for all panels, except for 20.3-cm, was of clear monofilament, double knotted and double selvaged. The 20.3-cm SM webbing was made of #28 multifilament nylon, single knotted, and double selvage. In 2005, a panel of net with 7.6 cm (3.0”) mesh size was added to the sampling gear and the 20.3 cm mesh panel was removed.

Survey design

Surveys were conducted monthly from April-October, occasionally March-November. The sampling gear was set at fixed stations or randomly set within each area based on depth strata and GPS location. The nets were checked and cleared of catch or pulled and reset every 1.0-2.0 hr. Sharks were measured to the nearest cm for body lengths (precaudal, fork, total, and stretch total length) and data for sex and life history stage (neonate, young-of-the-year, juvenile, adult) were recorded. Sharks that were in poor condition were sacrificed for life history studies and those in good condition were tagged and released. Environmental data were collected prior to sampling. Mid-water temperature (°C), salinity (ppt), and dissolved oxygen (mg l-1) was measured with a YSI Model 55 oxygen meter and light transmission (cm) was determined using a secci disk. Further details can be found in Carlson and Brusher (1999).

Index Development

Several categorical variables were constructed for analysis of gillnet data:

“Year” (14 levels): 1996-2009

“Area” (5 levels): location of gillnet set (Figure 1).

“SetBegin” (4 levels):
Dawn=0401-1000 hrs
Day=1001-1600 hrs
Dusk=1601-2200 hrs
Night=2201-0400 hrs

“Season” (3 levels):
Spring=Mar-May
Summer=Jun-Aug
Fall=Sep-Nov

"Setdepth" (2 levels):
Shallow=less than 5 meters
Deep=greater than 5 meters

"Gear" (2 levels):
Net 1=(mesh sizes 8.9– 14.0 cm and 20.3 cm)
Net 2=(mesh sizes 7.6-14.0 cm)

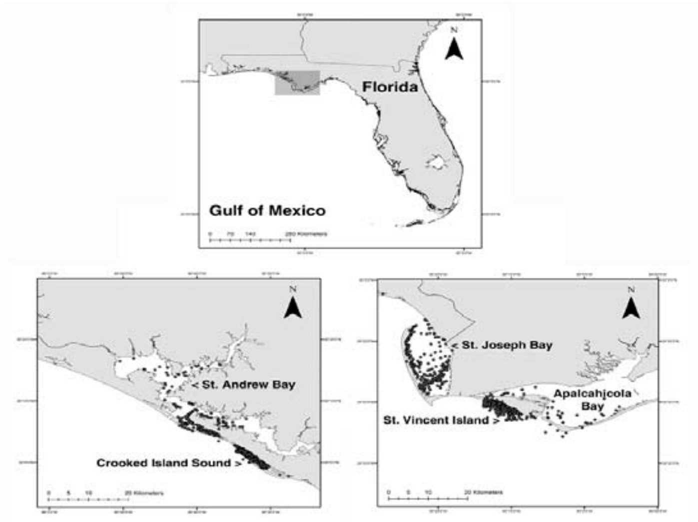
Because the change in gear in 2005 (i.e. gillnet mesh) could affect CPUE, in 2006 a randomization technique was used to test the null hypothesis of no difference in mean CPUE between sharks captured with net 1 and those with net 2. Each net was independently randomly fished throughout the sampling strata in order to provide robust samples when introducing gear into the generalized linear model. Analysis was run for the time series through 2006 although standardized abundance indices are only reported through 2005.

The proportion of sets that caught sharks (when at least one shark was caught) was modeled assuming a binomial distribution with a logit link function. The positive catches were modeled assuming a lognormal distribution. Initially, a null model was run with no factors entered into the model. Models were then fit in a stepwise forward manner adding one independent variable. Each factor was ranked from greatest to least reduction in deviance per degree of freedom when compared to the null model. The factor with the greatest reduction in deviance was then incorporated into the model providing the effect was significant at $p<0.05$ based on a Chi-Square test, and the deviance per degree of freedom was reduced by at least 1% from the less complex model. The process was continued until no factors met the criterion for incorporation into the final model. Regardless of its level of significance, year was kept in all final models. After selecting the set of fixed factors and interactions for each error distribution, all interactions that included the factor year were treated as random interactions (Ortiz and Arocha, 2004). This process converted the basic models from generalized linear models into generalized linear mixed models. The final model determination was evaluated using the Akaike Information Criteria (AIC), and Schwarz's Bayesian Criterion (BIC). Models with smaller AIC and BIC values are preferred to those with larger values. These models were fit using a SAS macro, GLIMMIX (glmm800MaOB.sas: Russ Wolfinger, SAS Institute Inc.) and the MIXED procedure in SAS statistical computer software (PROC GLIMMIX). Relative indices of abundance were calculated as the product of the year effect least square means from the two independent models.

RESULTS AND DISCUSSION

A total of 1320 gillnet sets have been made throughout 5 areas since 1996 (Figure 1).

Figure 1. Location of study site in northwest Florida near latitude 30° 00' N and longitude 85° 35' W. Locations of sets of fishing gear are represented by dots.



<u>Sandbar sharks</u>

For sandbar sharks, the proportion of positive sets (at least one sandbar shark was caught) was 3.1%. The stepwise construction of the models is summarized in Table 1. The standardized abundance index is shown in Figure 2. Because of the low proportion positives, only year was included in the final mixed model. To allow for visual comparison with the nominal values, both series were scaled to their respective maximum value. The index statistics can be found in Table 2. Table 3 provides a table of the frequency of observations by factor and level. Average sizes of sharks captured by year are reported in Table 4. Diagnostic plots assessing the fit of the lognormal model were deemed acceptable (Figure 3). The frequency distribution of the natural logarithm of CPUE, and residuals approximated a normal distribution. When plotted by year, the residuals were distributed evenly around zero. The quantile-quantile plot of the data tended to fall along the reference line indicating the data are from a normal distribution. In summary, all diagnostic plots met assumptions, and supported an acceptable fit to the selected model.

Table 1. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear and mixed model formulations of the proportion of positive and positive catches for sandbar sharks for all life stages. Final models selected are in bold.

Proportion positive-Binomial error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1303	329.4533	0.253				
YEAR	1290	275.2781	0.213	15.602	15.602	54.18	<.0001
YEAR+							
AREA	1287	197.5424	0.153	39.294	23.692	77.74	<.0001
SEASON	1288	272.2784	0.211	16.392		3	0.2232
SETBEGIN	1287	273.3548	0.212	15.996		Negative of Hessian not positive definite.	
SETDEPTH	1289	275.2239	0.214	15.553		0.05	0.8159
NET	1289	275.2781	0.214	15.536		Negative of Hessian not positive definite.	
MIXED MODEL	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR	**-18E307**	**-18E307**	**-18E307**				

Positive catches-Lognormal error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	35	34.8603	0.996				
YEAR	24	7.4051	0.309	69.022	69.022	55.77	<.0001
YEAR+							
SEASON	22	5.743	0.261	73.791	4.769	9.15	0.0103
SETBEGIN	22	5.9202	0.269	72.982		8.06	0.0178
SETDEPTH	23	6.9334	0.301	69.734		2.37	0.1237
NET	24	7.4051	0.309	69.022		0	.
AREA	23	7.4042	0.322	67.679		0	0.9473
MIXED MODEL	AIC	BIC	(-2) LOGLIKELIHOOD				
YEAR	**52.5**	**53.7**	**50.5**				

Table 2. The standardized and relative index (number of sharks per net hour) of absolute abundance, and coefficients of variation (CV) for sandbar shark. N=number of sets.

YEAR	N	ABSOLUTE STANDARDIZED INDEX	CV	ABSOLUTE NOMINAL INDEX	CV
1996	26	0.039	0.22	0.036	0.17
1997	27	0.075	0.31	0.081	0.30
1998	68	0.047	0.35	0.044	0.49
1999	49	0.019	0.57	0.019	0.70
2000	54	0.025	0.57	0.025	0.73
2001	91	0.040	0.35	0.046	0.68
2002	130	0.023	0.35	0.022	0.73
2003	150	0.037	0.25	0.035	0.55
2004	117	0.018	0.42	0.017	0.78
2005	149	0.012	0.42	0.011	0.88
2006	146	?	?	0.000	0.00
2007	143	0.030	0.35	0.028	0.74
2008	128	0.011	0.42	0.011	0.87
2009	82	0.077	0.28	0.089	0.47

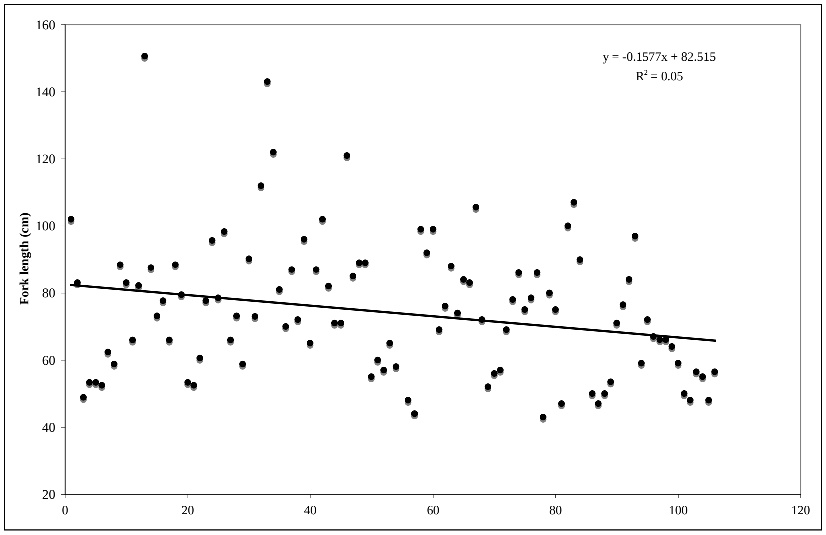


Figure 2. Lengths of sandbar sharks captured by year.

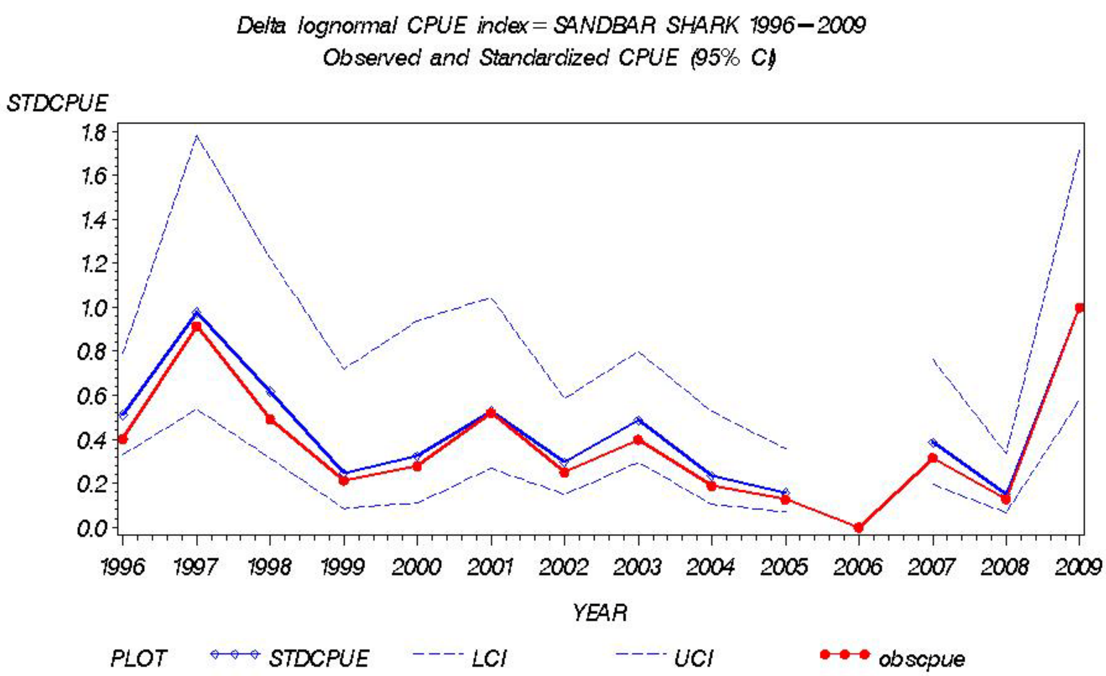
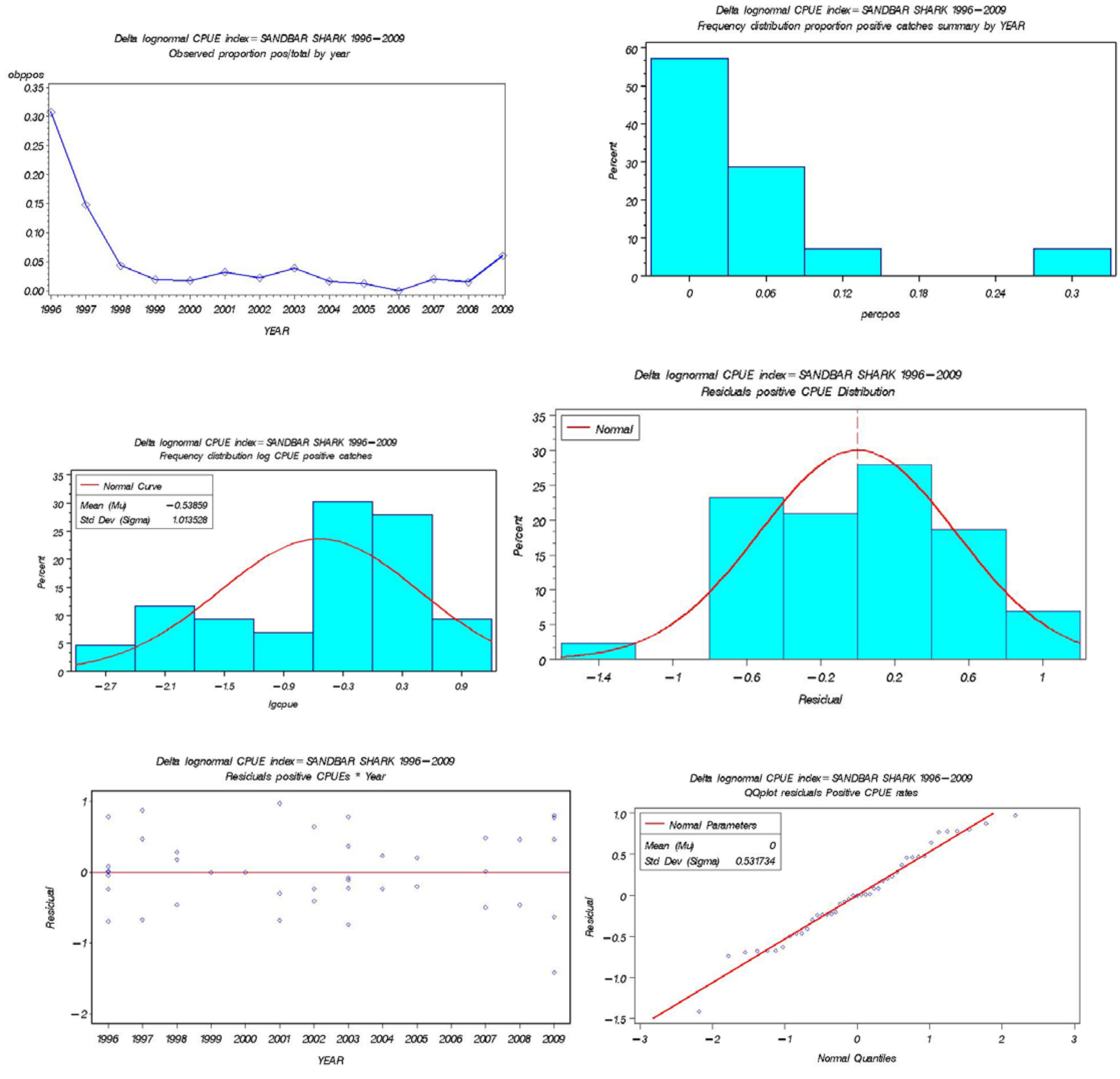


Figure 2. Nominal (obscpue) and standardized (STDCPUE) indices of abundance for sandbar shark. The dashed lines are the 95% confidence limits (LCL, UCL) for the standardized index. Each index has been divided by the maximum of the index

Table 3. Frequency of observations by factor and level used in the development of the standardized catch rate series.

FACTOR	LEVEL	FREQUENCY OF TOTAL
YEAR	1996	1.9
	1997	2.0
	1998	5.0
	1999	3.6
	2000	4.0
	2001	6.7
	2002	9.6
	2003	11.0
	2004	8.6
	2005	11.0
	2006	10.7
	2007	10.5
	2008	9.4
	2009	6.0
AREA	APL	2.9
	CIS	33.0
	IP	22.9
	SAB	18.2
	SJB	22.9
SEASON	FALL	25.0
	SPRING	27.1
	WINTER	47.9
SETDEPTH	<5.0 m	75.7
	>5.0 m	24.3
SETBEGIN	DAWN	46.3
	DAY	47.9
	DUSK	5.0
	NIGHT	0.8

Figure 3. Diagnostic plots of the frequency distribution of residuals, quantile-quantile plots, and distribution of residuals by year.



Blacknose sharks

Life history specific stage (e.g. adult, juvenile) catch rates were constructed for blacknose shark. The proportion of positive sets (at least one blacknose shark was caught) was 2.3% for adults and 8.6% for juveniles (Age 0-4).

The stepwise construction of the models is summarized in Table 5. Because of the low proportion positives, a stepwise reduction in factors was not conducted and only year was included in a final mixed model for adult sharks. The standardized abundance index is shown in Figure 4. The index statistics can be found in Table 6. Sizes of sharks captured by year are found in Figure 5. Diagnostic plots assessing the fit of the model were deemed acceptable (Figure 6).

Table 5. Analysis of deviance of explanatory variables for the binomial and lognormal generalized linear and mixed model formulations of the proportion of positive and positive catches for blacknose sharks for juvenile stages. Final models selected are in bold.

Proportion positive-Binomial error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	1358	797.4703	0.587				
YEAR	1345	734.7481	0.546	6.975	6.975	62.72	<.0001
YEAR+							
AREA	1341	635.563	0.474	19.292	12.318	99.19	<.0001
SEASON	1343	704.5869	0.525	10.660		30.16	<.0001
SETDEPTH	1344	704.5049	0.524	10.737		30.24	<.0001
SETBEGIN	1342	728.9448	0.543	7.503		5.8	0.1216
NET	1344	734.6573	0.547	6.917		0.09	0.7632
YEAR+AREA							
SEASON	1339	601.1888	0.449	23.543	4.251	34.37	<.0001
SETDEPTH	1340	619.6518	0.462	21.254		15.91	<.0001
YEAR+AREA+SEASON							
SETDEPTH	1338	585.4574	0.438	25.488	1.945	15.73	<.0001
MIXED MODEL	**AIC**	**BIC**	**(-2) LOGLIKELIHOOD**				
YEAR+AREA+SEASON+SETDEPTH	**1385.4**	**1388.8**	**1383.4**				
YEAR+AREA+SEASON+SETDEPTH YEAR*AREA	1389.8	1393.9	1385.8				
YEAR+AREA+SEASON+SETDEPTH YEAR*SEASON	1458.1	1461.6	1454.1				
YEAR+AREA+SEASON+SETDEPTH YEAR*SETDEPTH	1456.2	1457.5	1454.2				
Positive catches-Lognormal error distribution							
FACTOR	**DF**	**DEVIANCE**	**DEVIANCE/DF**	**%DIFF**	**DELTA%**	**CHISQUARE**	**PR>CHI**
NULL	116	79.2613	0.683				
YEAR	103	45.494	0.442	35.358		64.95	<.0001
YEAR+							
SETBEGIN	100	41.2418	0.412	39.642	4.284	11.48	0.0094
AREA	100	44.0547	0.441	35.525		3.76	0.2884
SETDEPTH	102	45.4838	0.446	34.739		0.03	0.8713
NET	102	45.4922	0.446	34.727		0	0.9458
SEASON	101	45.2491	1.157	-69.396		0.63	0.7292
MIXED MODEL	**AIC**	**BIC**	**(-2) LOGLIKELIHOOD**				
YEAR+SETBEGIN	**230.4**	**233.0**	**228.0**				
YEAR+SETBEGIN YEAR*SETBEGIN	230.4	231.8	228.4				

Table 6. The standardized and relative index (number of sharks per net hour) of absolute abundance, and coefficients of variation (CV) for adult blacknose sharks. N=number of sets.

YEAR	N	ABSOLUTE STANDARDIZED INDEX	CV	ABSOLUTE NOMINAL INDEX	CV
1996	26	0.023	0.31	0.025	0.31
1997	27	0.013	0.43	0.012	0.38
1998	68	0.033	0.31	0.038	0.48
1999	49	-		0.000	0.00
2000	54	-		0.000	0.00
2001	91	0.020	0.43	0.020	0.74
2002	130	0.019	0.36	0.017	0.67
2003	150	0.016	0.36	0.014	0.70
2004	117	0.038	0.36	0.040	0.73
2005	149	0.029	0.36	0.029	0.76
2006	146	-		0.000	0.00
2007	143	0.010	0.43	0.009	0.84
2008	128	0.048	0.31	0.043	0.59
2009	82	0.011	0.58	0.011	0.91

Table 7. The standardized and relative index (Number of sharks per net hour) of absolute abundance, and coefficients of variation (CV) for juvenile blacknose sharks. N=number of sets.

YEAR	N	ABSOLUTE STANDARDIZED INDEX	CV		ABSOLUTE NOMINAL INDEX	CV
1996	26	0.44	0.32		0.19	0.21
1997	27	0.26	0.42		0.13	0.19
1998	68	0.12	0.62		0.16	0.34
1999	49	0.43	0.50		0.24	0.31
2000	54	0.02	4.14		0.01	0.73
2001	91	0.16	0.68		0.08	0.36
2002	130	0.21	0.52		0.10	0.34
2003	150	0.20	0.47		0.12	0.33
2004	117	0.15	0.61		0.11	0.36
2005	149	0.11	1.29		0.06	0.81
2006	146	0.14	0.93		0.08	0.55
2007	143	0.19	0.58		0.12	0.41
2008	128	0.17	0.68		0.10	0.49
2009	82	0.12	1.07		0.09	0.59

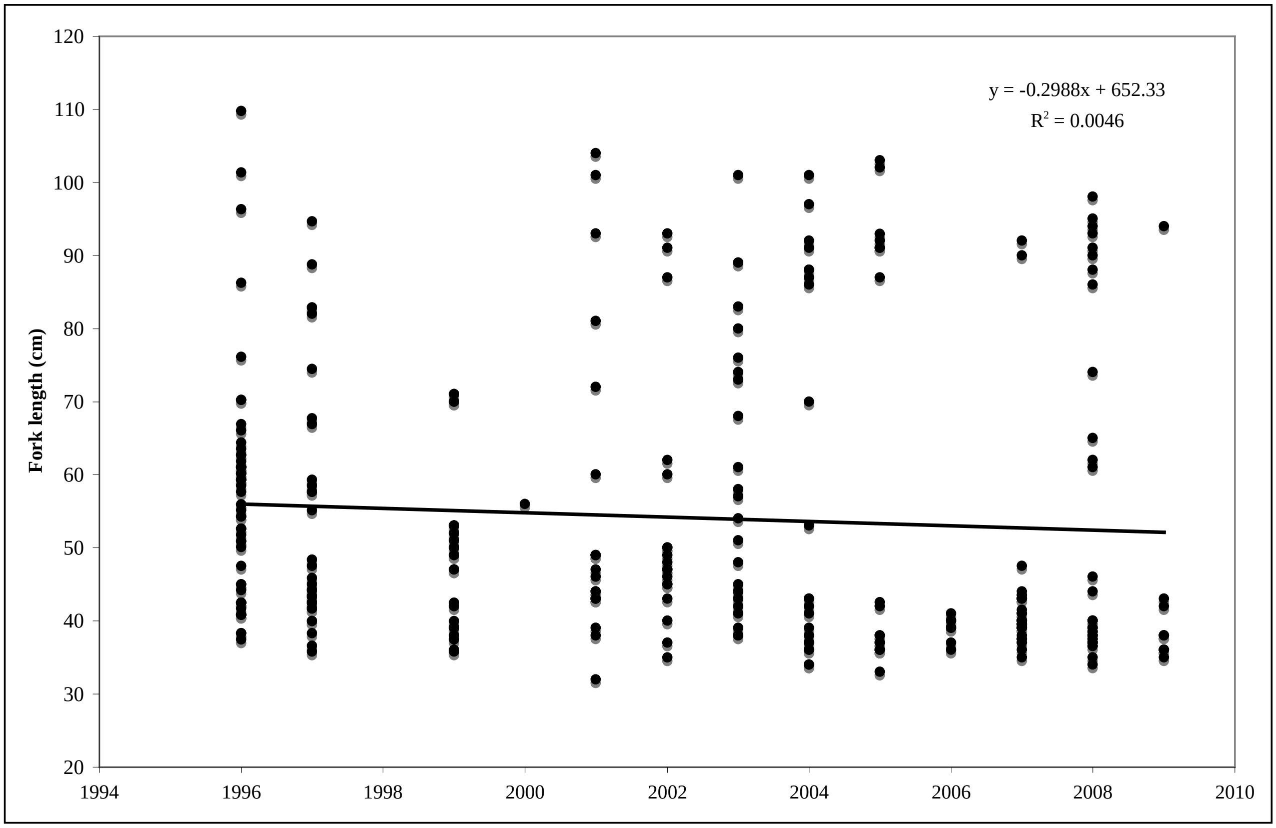


Figure 3. Lengths of blacknose sharks collected by year during fishery independent sampling.

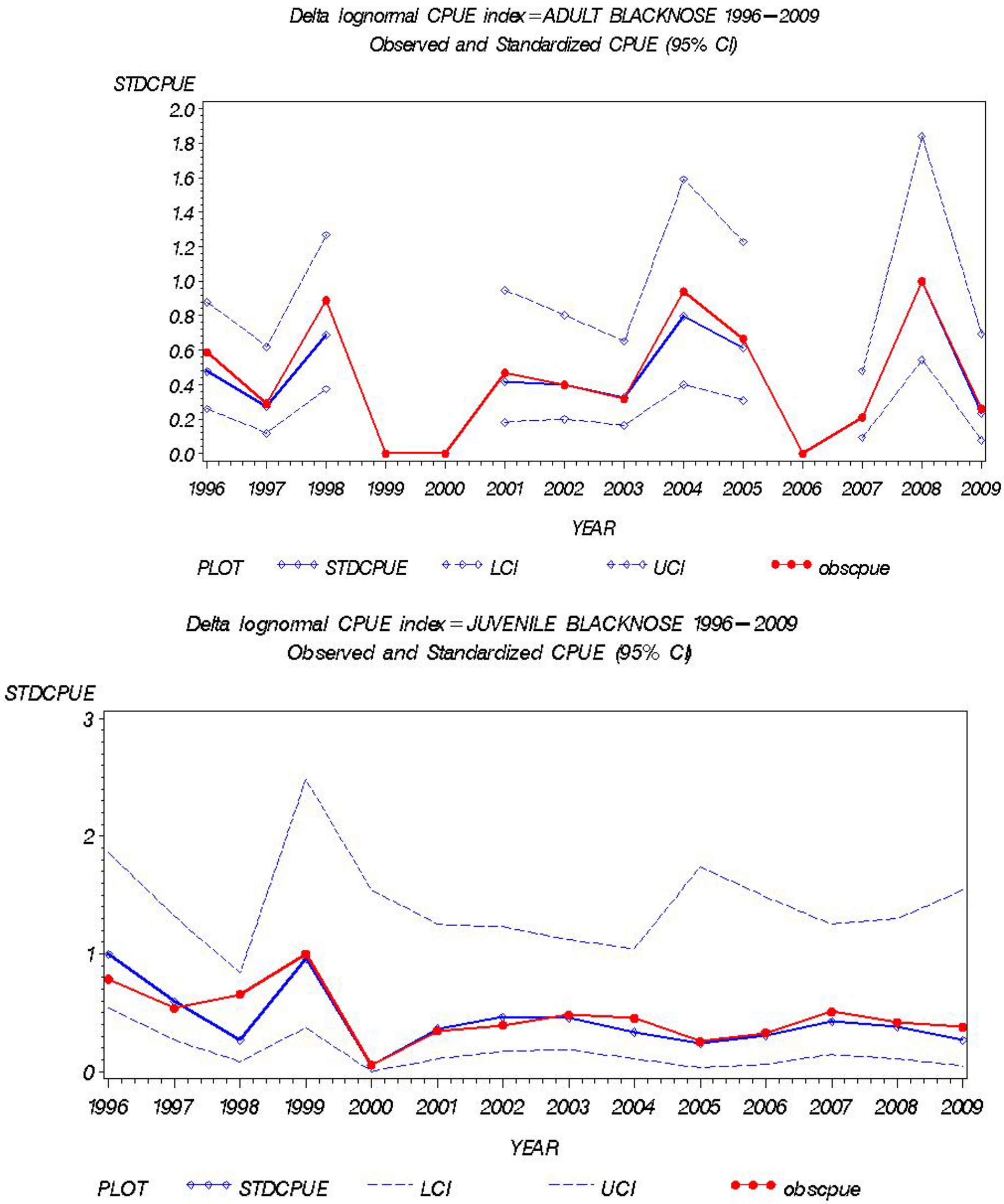
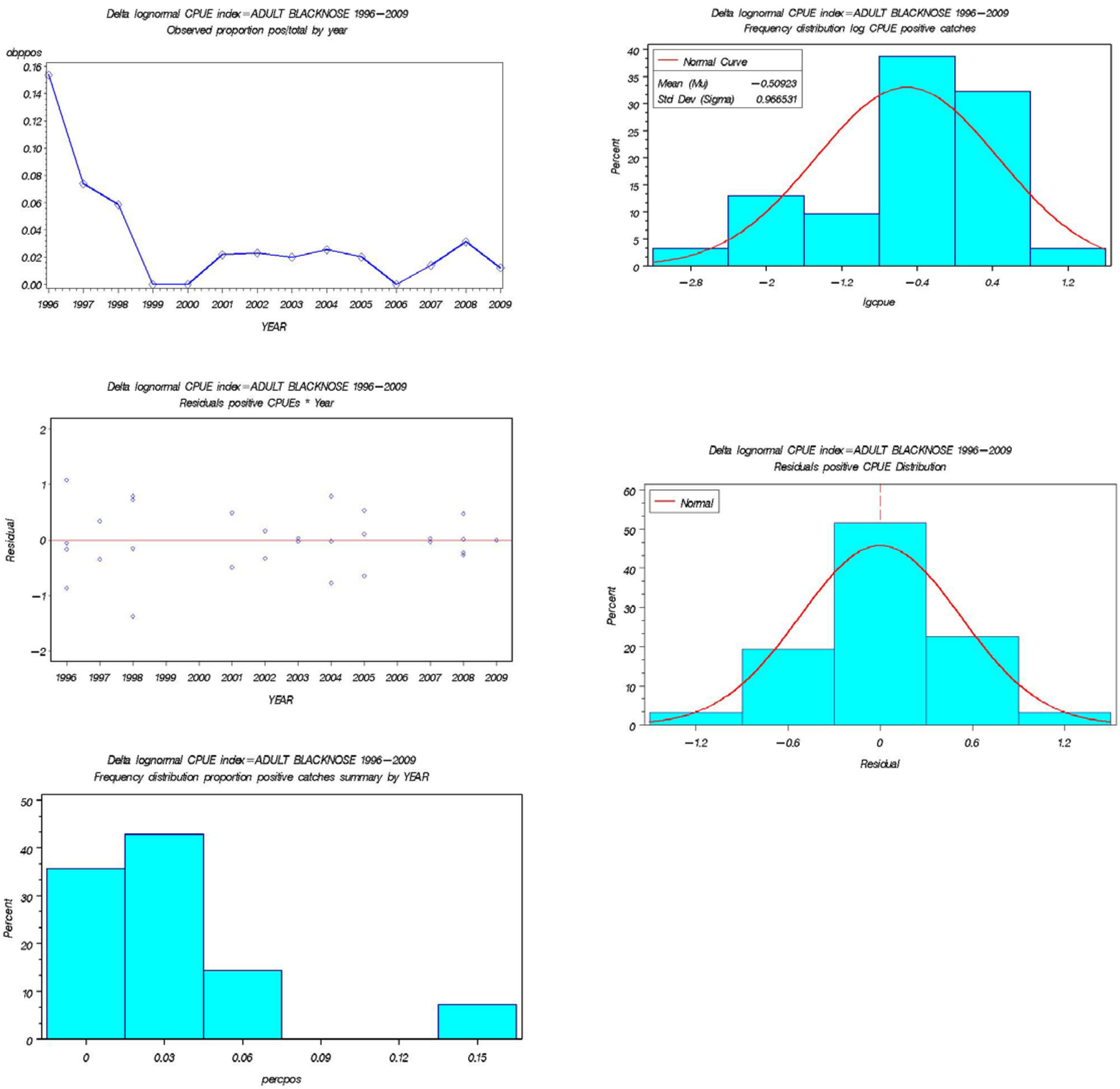
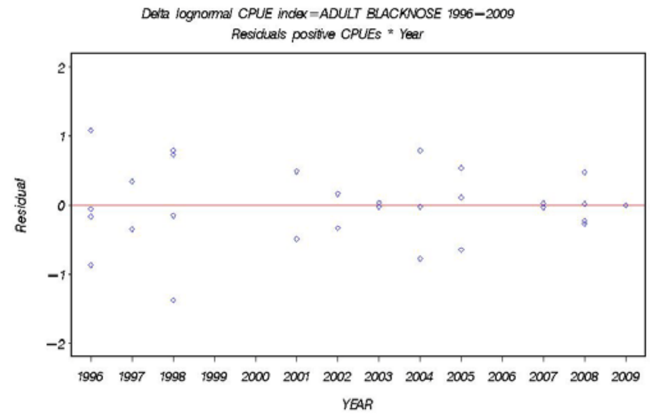


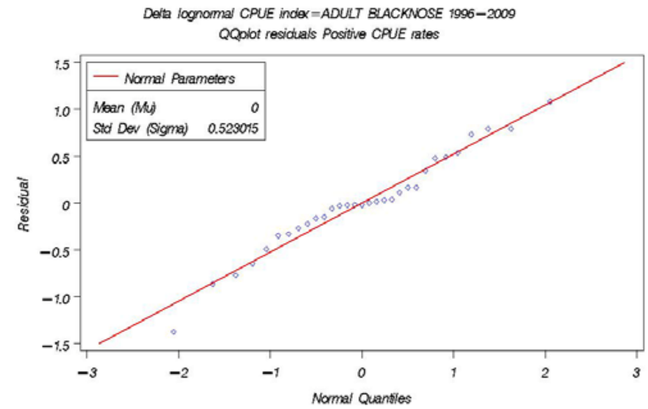
Figure 4. Nominal (obscpue) and standardized (STDCPUE) indices of abundance for blacknose shark. The dashed lines are the 95% confidence limits (LCL, UCL) for the standardized index. Each index has been divided by the maximum of the index

Figure 5. Diagnostic plots of the frequency distribution of residuals, quantile-quantile plots, and distribution of residuals by year for blacknose shark.

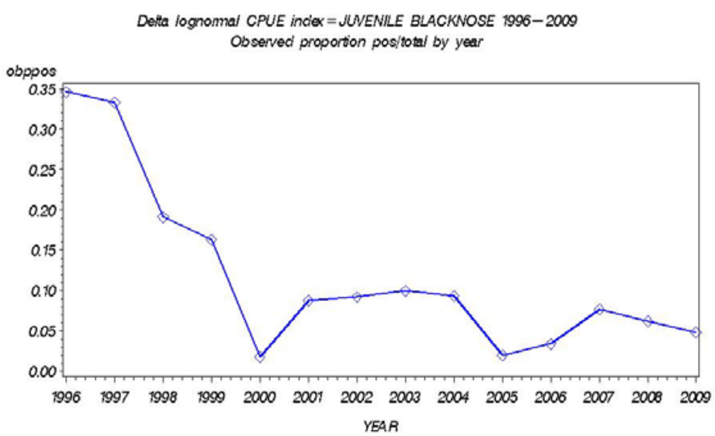
ADULT

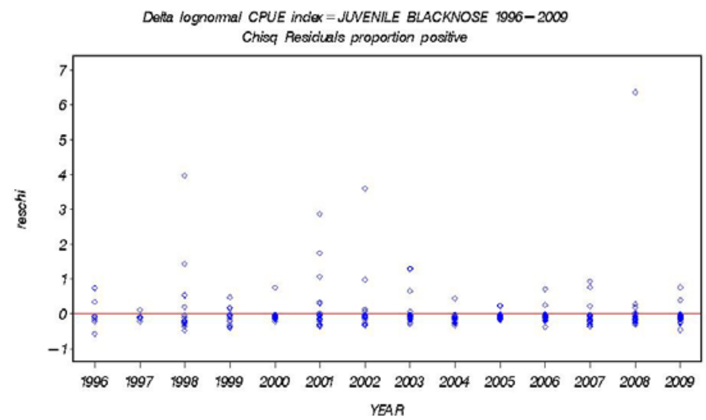


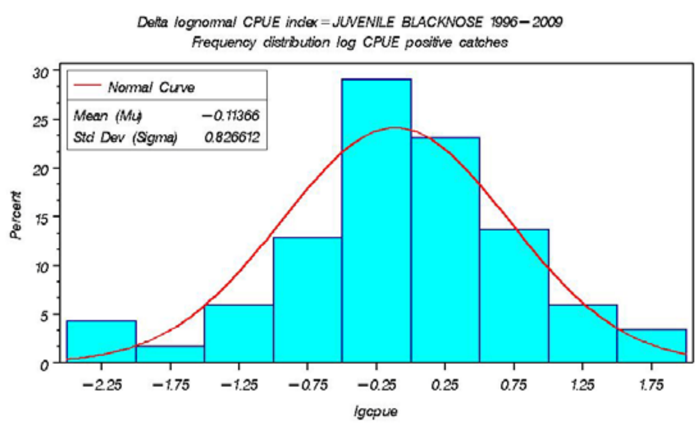

Delta lognormal CPUE index=ADULT BLACKNOSE 1996−2009
Residuals positive CPUEs * Year
Residual
YEAR

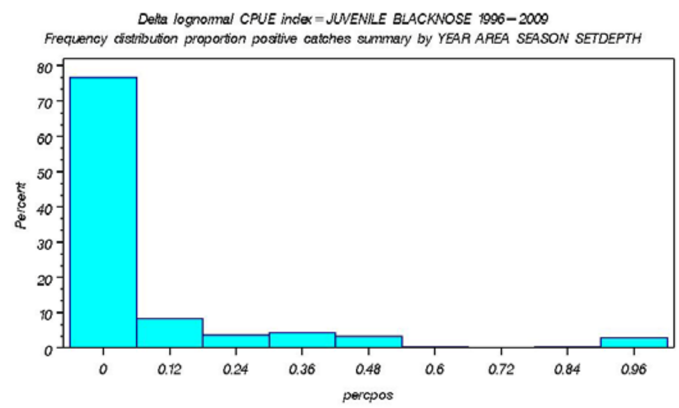

Delta lognormal CPUE index=ADULT BLACKNOSE 1996−2009
QQplot residuals Positive CPUE rates
Normal Parameters
Mean (Mu) 0
Std Dev (Sigma) 0.523015
Residual
Normal Quantiles

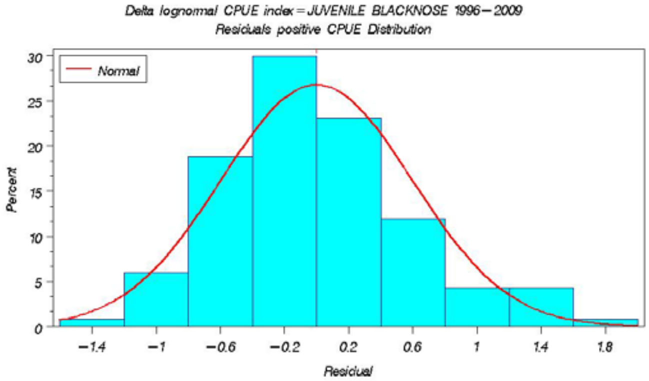
JUVENILE

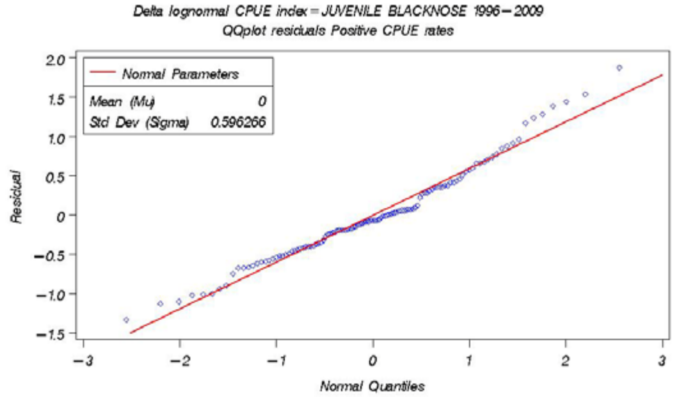

Delta lognormal CPUE index=JUVENILE BLACKNOSE 1996−2009
Observed proportion pos/total by year
obppos
YEAR

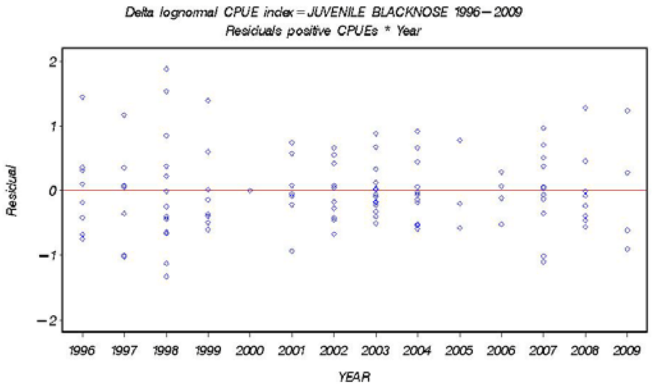

Delta lognormal CPUE index=JUVENILE BLACKNOSE 1996−2009
Chisq Residuals proportion positive
reschi
YEAR


Delta lognormal CPUE index=JUVENILE BLACKNOSE 1996−2009
Frequency distribution log CPUE positive catches
Normal Curve
Mean (Mu) −0.11366
Std Dev (Sigma) 0.826612
Percent
lgcpue


Delta lognormal CPUE index=JUVENILE BLACKNOSE 1996−2009
Frequency distribution proportion positive catches summary by YEAR AREA SEASON SETDEPTH
Percent
percpos


Delta lognormal CPUE index = JUVENILE BLACKNOSE 1996-2009
Residuals positive CPUE Distribution
Normal
Percent
Residual


Delta lognormal CPUE index = JUVENILE BLACKNOSE 1996-2009
QQplot residuals Positive CPUE rates
Normal Parameters
Mean (Mu) 0
Std Dev (Sigma) 0.596266
Residual
Normal Quantiles


Delta lognormal CPUE index = JUVENILE BLACKNOSE 1996-2009
Residuals positive CPUEs * Year
Residual
YEAR